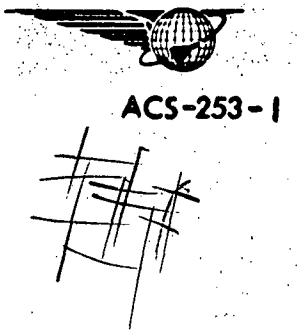
ACS AVION SYSTEMS REVIEW

LOCKHEED MISSILES & SPACE COMPANY
A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION
SUNNYVALE, CALIFORNIA

ACS AVIONICS SYSTEMS REVIEW



Presentation To NASA-MSC 18 February 1972

NASA-26362 - PHASE B EXTENSION

LOCKHEED MISSILES & SPACE COMPANY, INC./SUNNYVALE, CALIFORNIA

STUDY OBJECTIVES

REFINE THE BASELINE AVIONICS SYSTEM DESIGN

CLARIFY KEY ISSUES FOR RFP

REFINE THE BASELINE AVIONICS SYSTEM COSTS

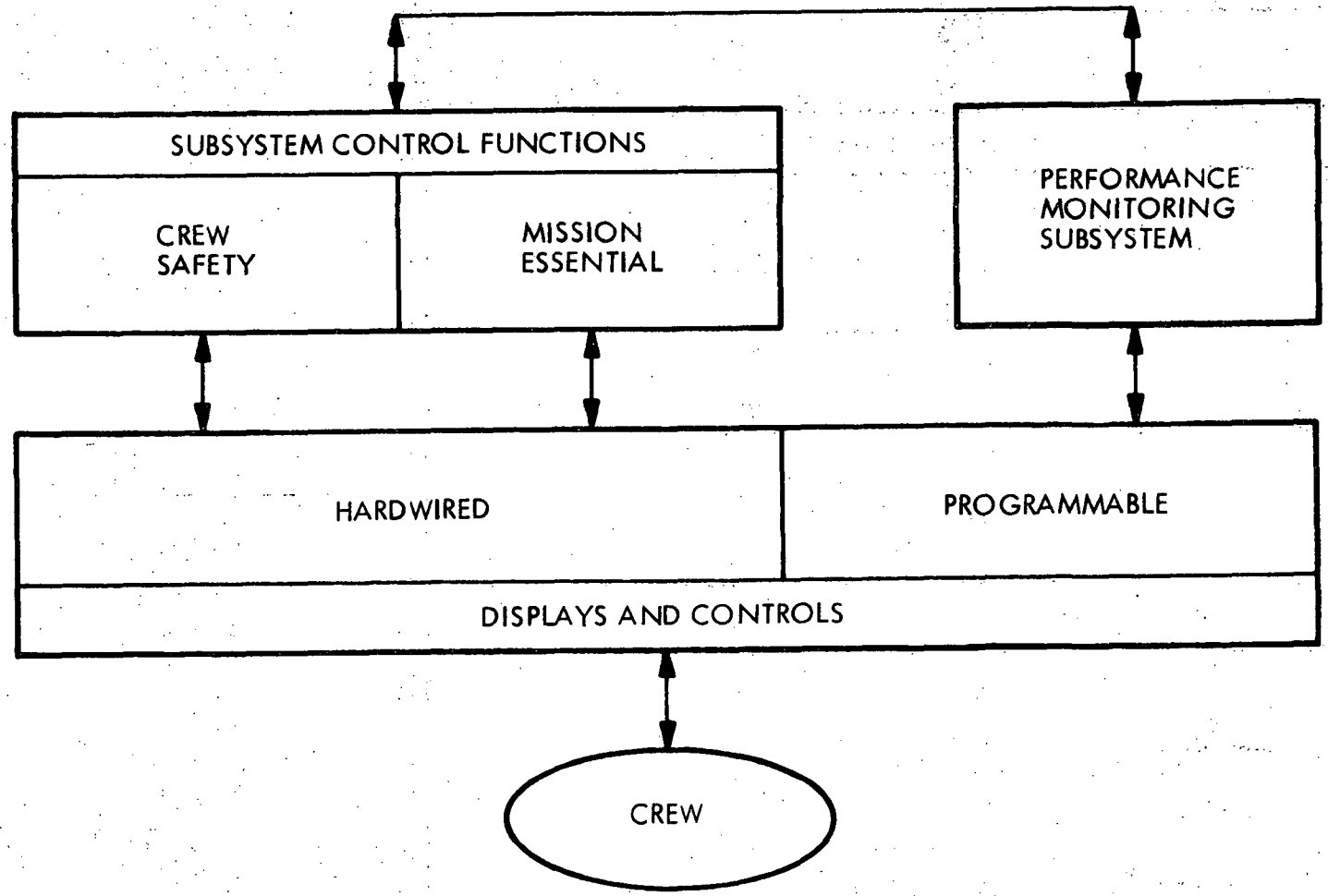
AVIONICS TASKS & PRIORITIES

PRIORITY	TASK
1	DEVELOP DETAIL SYSTEM PER TD 3009 BASELINE REQUIREMENTS
2	EVALUATE MODE FOR ORBITER CONTROL BLENDING
3	TRADEOFF DIGITAL VS ANALOG AERO FLIGHT CONTROL SYSTEMS
4	ASSESS INTEGRATION OF A/C AND S/C FLIGHT CONTROL COMPUTERS
5	EVALUATE GIMBAL VS STRAPDOWN IMU
6	INVESTIGATE A BACKUP FOR A GENERIC SOFTWARE FAILURE
7	EVALUATE FEASIBILITY AND DESIRABILITY OF MONITORING AND/OR GROUND CONTROL OF ONBOARD SWITCHES AND CIRCUIT BREAKERS DURING CHECKOUT
8	PROVIDE AN AUTOMATIC LANDING SYSTEM DESIGN APPLICABLE TO UNMANNED FIRST VERTICAL FLIGHT AND DEFINE THE PHASED INSTALLATION AT THE MOST ECONOMICAL TIME DURING THE PROGRAM
9	DEVELOP COSTS FOR THE BASELINE SYSTEM
10	EVALUATE TECHNIQUES FOR OBTAINING AND DISPLAYING RENDEZVOUS RANGE RATE

LOCKHEED'S APPROACH TO AVIONICS

- USE DEVELOPED SYSTEMS OR EQUIPMENT GROUPS
  - HARDWARE
  - SOFTWARE
- RETAIN FULL CAPABILITY WITHIN MINIMUM TECHNOLOGY CONSTRAINT
- TRADEOFF RELATED COST ELEMENTS PRIOR TO SYSTEM SELECTION
- SELECT AVIONICS CONFIGURATION CAPABLE OF PERFORMANCE GROWTH WITH MINIMUM SYSTEM IMPACT

ORBITER AVIONICS SYSTEM CONCEPT



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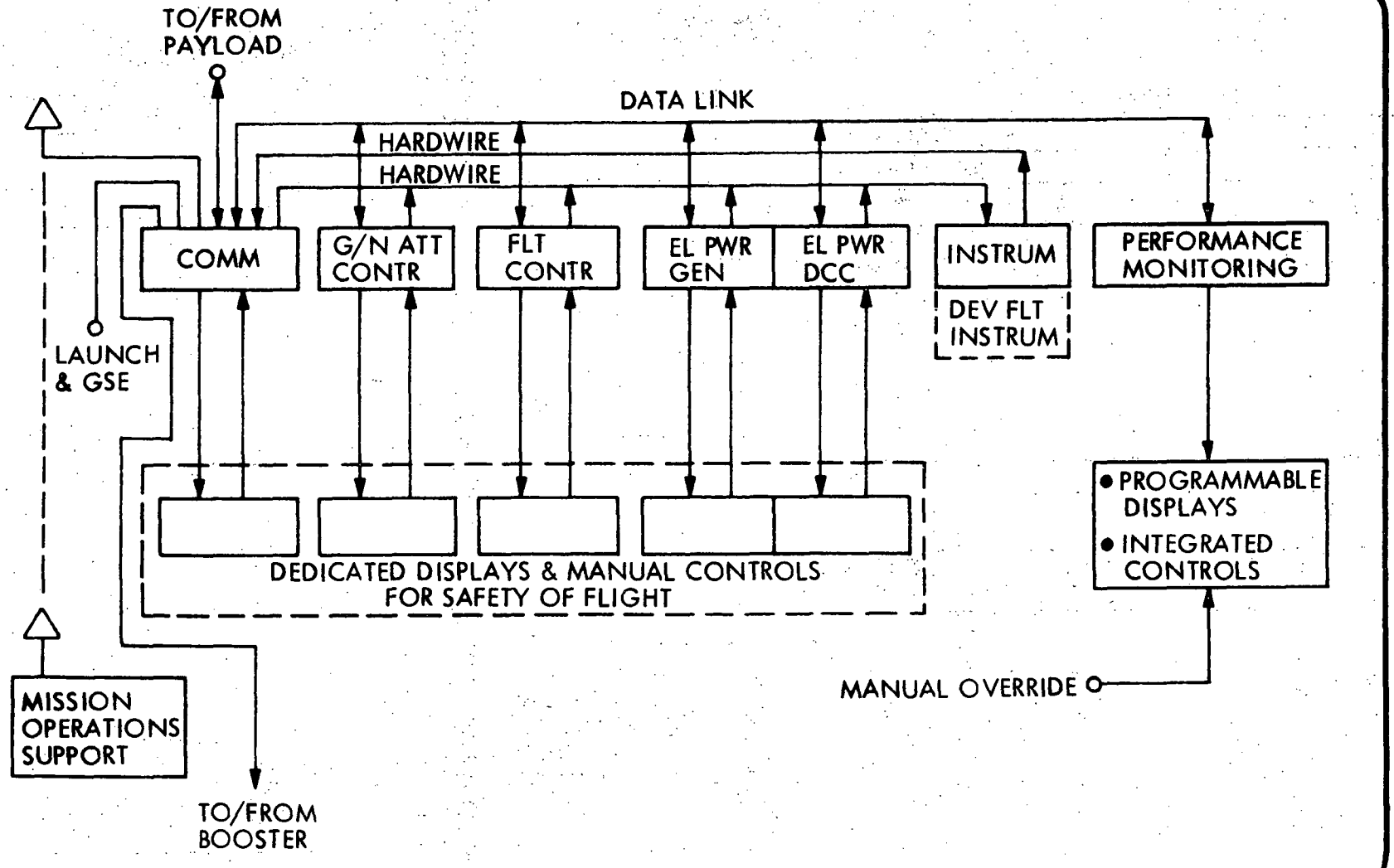
ORBITER AVIONICS BASELINE



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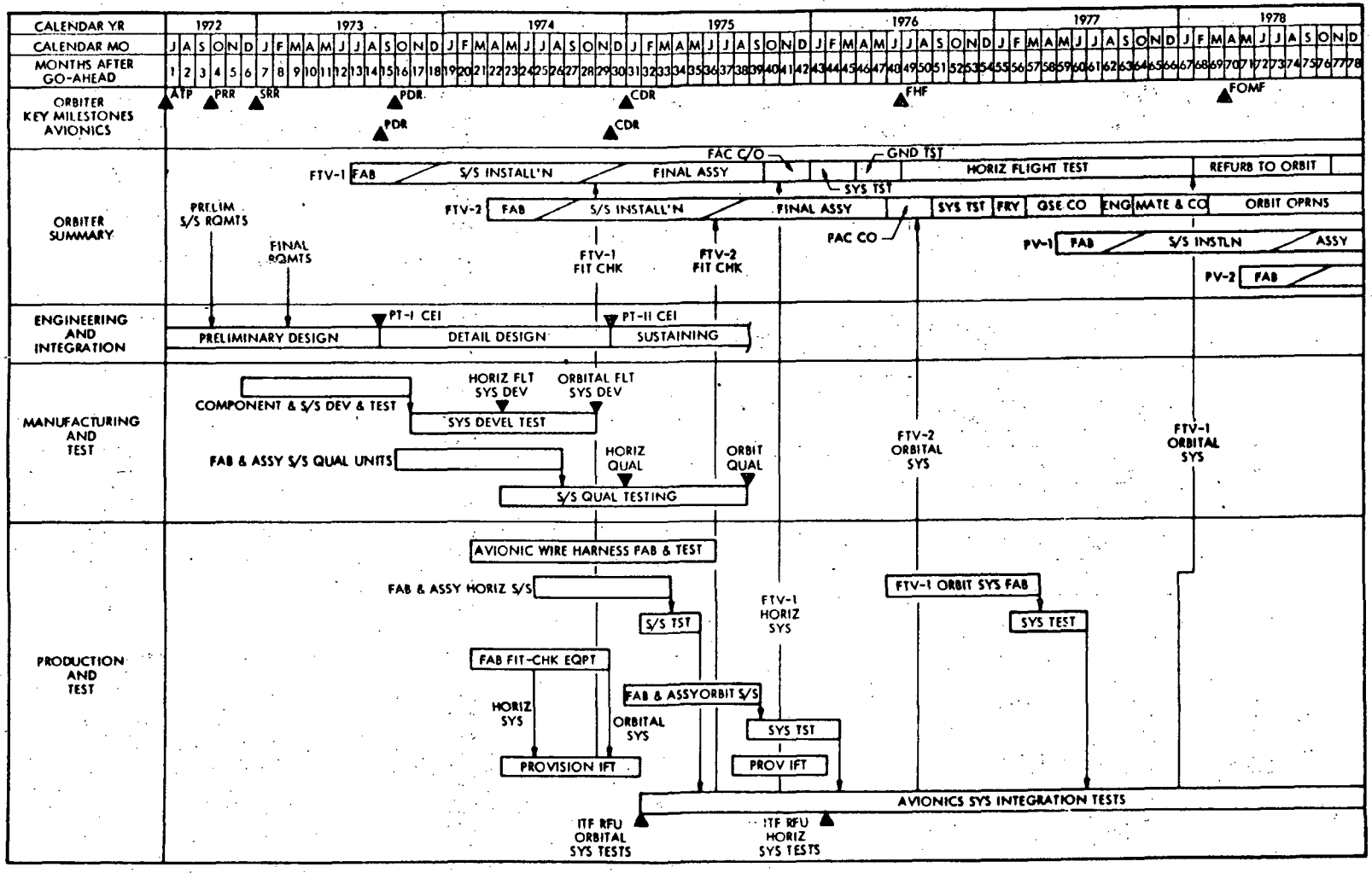
DEVELOPMENT SCHEDULE



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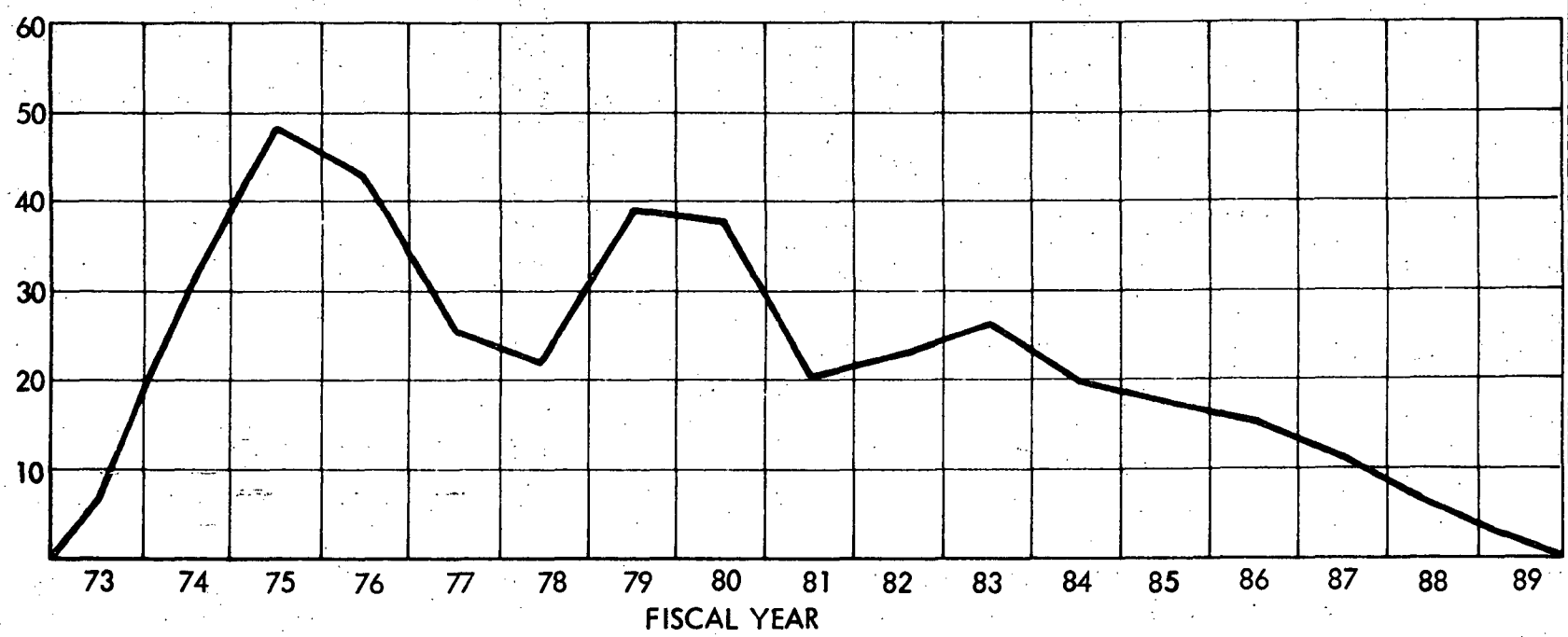
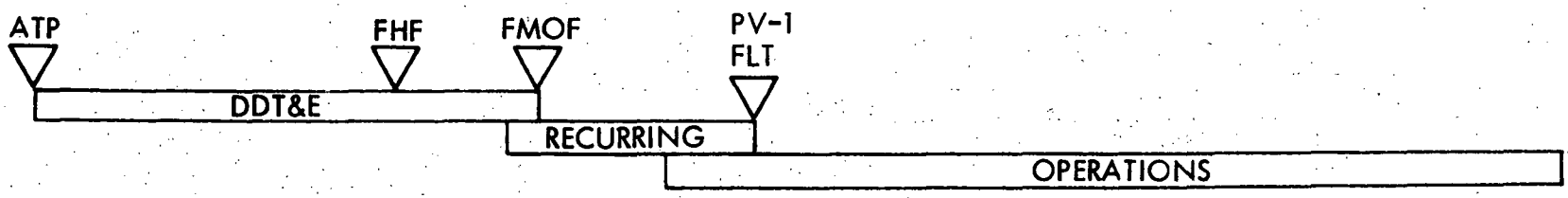
ORBITER AVIONICS PEAK ANNUAL COSTS W/MILESTONES





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COST STRUCTURE AND BUILDUP

COST $ MILLIONS

ORBITER AVIONICS 386.5

166.8 - DDT&E

114.1 - DESIGN & DEVELOP*
- 6.7 - AVIONICS MGMT
- 6.7 - SUBSYS MGMT & INTEG
- 67.4 - HDWE/SOFTWARE DESIGN
- 0.3 - AVIONIC SPECIAL FACIL
- 5.8 - SUBCONTRACTOR MGMT
- 22.5 - SUBCONTR/VENDOR EFFORT
- 4.7 - DEVELOPMENT TEST

25.3 - GROUND TEST
- 15.2 - GRND TEST HDWE (1.5 SETS)
- 5.4 - GROUND TEST LABOR
- 4.2 - QUAL TEST (CONTR)
- 0.5 - GROUND HDLG EQUIP (AGE)

24.1 - FLIGHT TEST HDWE
- 7.0 - FTV-1 INCLDG FAB, ASSY, INSTL, DFI
- 17.1 - FTV-2 INCLDG FAB, ASSY, INSTL, DFI

3.3 - TOOLING
- 2.8 - LABOR (DESIGN & FAB)
- 0.5 - MATERIAL

90.3 - RECURRING

30.4 - REFURB FTVs
- 1.3 - AVIONICS MGMT
- 11.0 - S/S MGMT & INTEG
- 12.6 - HDWE
- 5.5 - FAB, ASSY, INSTL

59.9 - PRODUCTION (3)
- 2.6 - S/S MGMT & INTEG
- 4.5 - SUSTAINING ENGRG
- 36.8 - PV-1, PV-2, PV-3 HDWE
- 16.0 - FAB, ASSY, INSTL

129.4 - OPERATIONS

61.3 - SUSTAINING**
- 8.0 - AVIONICS MGMT
- 45.3 - SUSTAINING ENGRG
- 8.0 - S/S MGMT & INTEG

29.8 - OPERATIONS
- 20.8 - FLT & LAUNCH SUPPORT
- 9.0 - FLT DATA REDUCTION

38.3 - SPARES
- 19.2 - SPARES (2 SETS)
- 19.1 - REPAIRS

* INCLUDES 13.3M FOR IMPROVED CAPABILITY DESIGN AND DEVELOPMENT
**INCLUDES 8.7M FOR IMPROVED CAPABILITY SYSTEM

ORBITER AVIONICS PROGRAM COSTS

$ MILLIONS

SUBSYSTEM	D&D	GRD TEST	FTH (2)	TOOLING	DDT&E	TFU	PROD (3)	REFURB/ RETROFIT	OPNS SPARES
AVIONICS SYS INTEG	6.7	-	-	-	6.7	-	-	1.3	8.0
GN&C	17.7	6.5	5.0	0.5	29.7	4.2	14.8	3.5	26.5
DISPLAYS & CONT	9.9	3.6	1.7	0.6	15.8	1.1	3.6	1.0	15.2
COMM AND TRACKING	8.1	4.7	5.7	0.4	18.9	3.5	12.0	1.7	12.2
ELECT PWR DIST & CONTROL	3.7	0.8	0.3	0.4	5.2	0.2	1.1	0.1	0.9
PERF MONITORING	16.6	6.4	4.1	0.8	27.9	4.1	13.4	9.9	39.9
INSTRUMENTATION									
OPERATIONAL	11.4	2.0	-	0.2	13.6	4.5	15.0	12.9	11.7
DFI	9.0	1.3	7.3	0.4	18.0	-	-	-	
SOFTWARE (VEHICLE)	31.0	-	-	-	31.0				15.0
AVIONICS SYST SUBTOTAL	114.1	25.3	24.1	3.3	166.8	17.6	59.9	30.4	129.4
			AVIONICS SYSTEM TOTAL						$ 386.5M
ELECT POWER GENERATION SYS	14.8	3.7	1.6	0.2	20.3	1.5	5.0	1.5	11.1
			ELECTRICAL POWER GENERATION TOTAL						$ 37.9M

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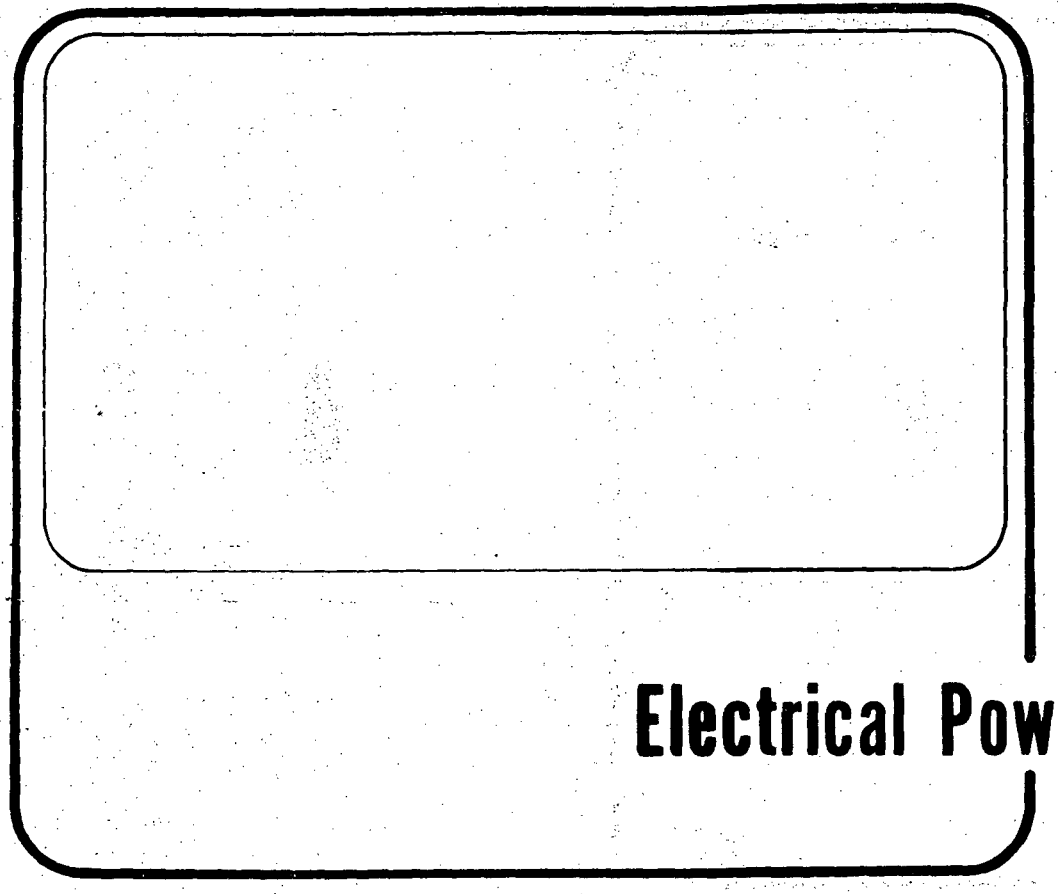


Electrical Power

ACS Avionics Review

ORBITER EPS BASELINE DESIGN REQUIREMENTS

UTILIZE MINIMUM TECHNOLOGY AND PROVIDE LOW COST DESIGN

100-MISSION LIFE WITH 10-YEAR SERVICE LIFE

7-DAY SELF-SUSTAINING LIFE, GROWTH TO 30-DAYS

REDUNDANCY - NOMINALLY FAIL OPERATIONAL/FAIL SAFE

PROVIDE PHYSICAL SEPARATION OF REDUNDANT PATHS

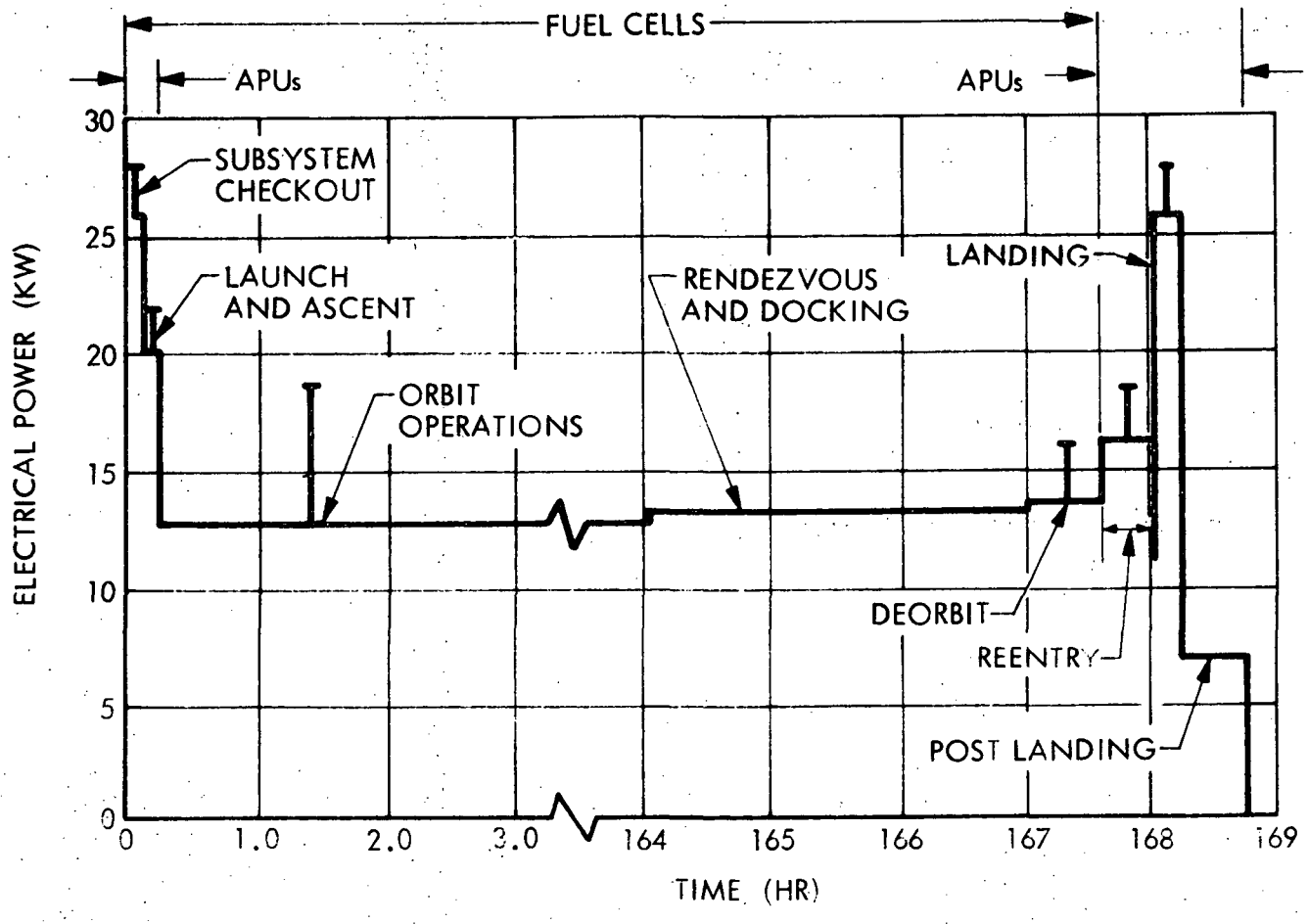
PROVIDE 28 VDC AND 115 VAC, 400 HZ NOMINALLY TO USERS

POWER AT USER TERMINAL IN ACCORDANCE WITH MIL-STD-704A

UTILIZE DEVELOPED AIRCRAFT EQUIPMENT VS NEW DEVELOPMENTS

HARDWIRE CONTROL OF SAFETY CRITICAL FUNCTIONS

ORBITER



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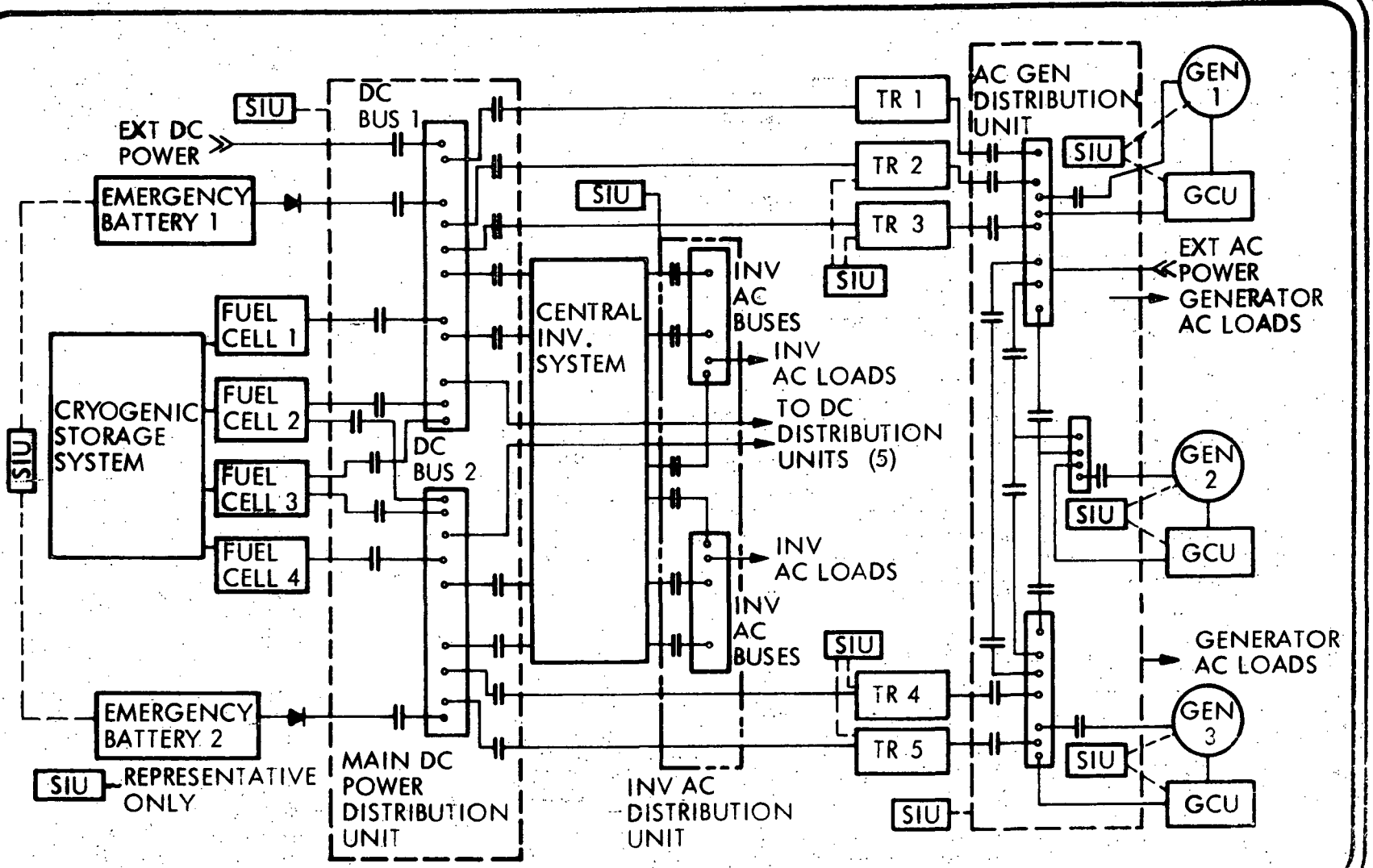
SPACE SHUTTLE ORBITER EPS



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ELECTRICAL POWER SYSTEM REQUIREMENTS

POWER USERS	HORIZONTAL FLIGHT	LAUNCH AND ASCENT	ORBITAL FLIGHT ORBIT OPERATIONS	ORBITAL FLIGHT APPROACH AND LANDING
AIRCRAFT SUBSYSTEMS	14 KW			14 KW
ABES FUEL BOOSTER PUMPS	8 KW			8 KW
ROCKET ENGINE PROPELLANT CIRCULATION FOLLOWING LOADING		7.5 KW		
SPACECRAFT SUBSYSTEMS		11 KW		

MISSION		ENERGY	
3 HR	HORIZONTAL FLIGHT	75	KW-HR
12 HR	ORBITAL PAYLOAD LAUNCH	192	KW-HR
7 DAY	LOGISTICS	2095	KW-HR

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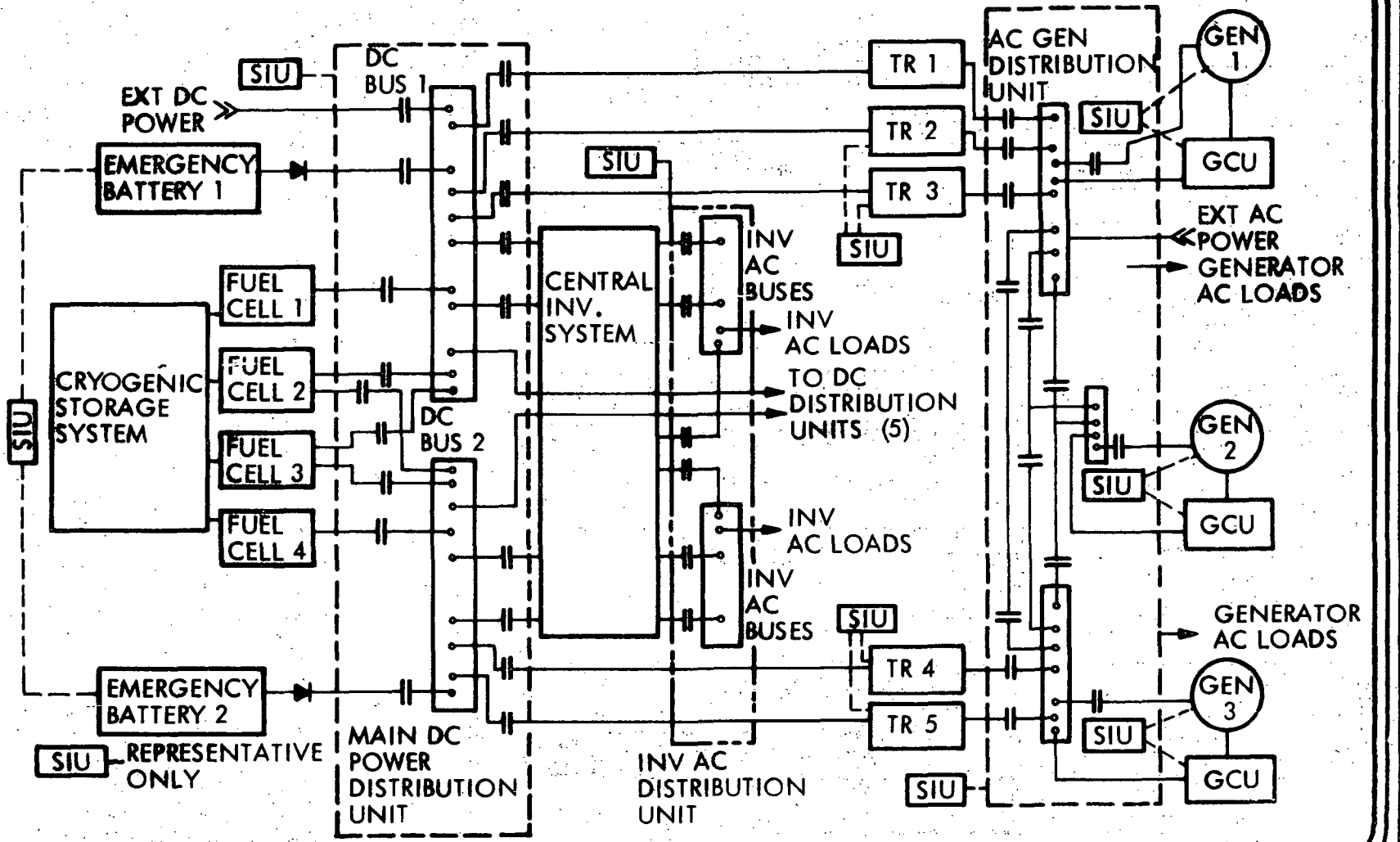
SIU
EXT DC POWER
EMERGENCY BATTERY 1
FUEL CELL 1
FUEL CELL 2
FUEL CELL 3
FUEL CELL 4
CRYOGENIC STORAGE SYSTEM
SIU
EMERGENCY BATTERY 2
SIU REPRESENTATIVE ONLY
DC BUS 1
DC BUS 2
MAIN DC POWER DISTRIBUTION UNIT
SIU
CENTRAL INV. SYSTEM
INV AC BUSES
INV AC LOADS
TO DC DISTRIBUTION UNITS (5)
INV AC LOADS
INV AC BUSES
INV AC DISTRIBUTION UNIT
TR 1
TR 2
TR 3
SIU
TR 4
TR 5
SIU
AC GEN DISTRIBUTION UNIT
SIU
SIU
SIU
SIU
GEN 1
GCU
EXT AC POWER
GENERATOR AC LOADS
GEN 2
GCU
GENERATOR AC LOADS
GEN 3
GCU
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EPS EQUIPMENT SELECTION CONSIDERATIONS

POWER GENERATION

EQUIP	CANDIDATES	SELECTION RATIONALE
H_2-O_2 FUEL CELLS	APOLLO 1.4 KW **NEW DESIGN 8 KW**	APOLLO DESIGN HAS LIMITED LIFE (400 HR) AND COST OF STARTUP SIMILAR TO NEW DESIGN. NEW INTERIM DESIGN TO HAVE 2000-HR LIFE
GENERATORS	**AC** OR DC **SPRAY-OIL COOLED** DUCTED-OIL COOLED **NON-PARALLEL** OR PARALLEL OPS	AC POWER MEETS REQUIREMENTS OF AVAILABLE LIGHTWEIGHT PUMP MOTORS. SPRAY OIL COOLED PROVIDES LIGHTWEIGHT DESIGN, NO OIL LEAKAGE BUT SOME ZERO-G DEVELOPMENT. NON-PARALLEL OPERATION AVOIDS SYNCHRONOUS OPERATION OF APUs OR CONSTANT SPEED DRIVES
BATTERIES	**Ni-CD** OR AG-ZN	SEALED Ni-CD IS HEAVIER DESIGN BUT REQUIRES LESS FACILITY SUPPORT AND PROVIDES MORE OPERATIONAL CYCLES.

EPS EQUIPMENT CONSIDERATIONS

POWER DISTRIBUTION CONDITIONING AND CONTROL

EQUIP	CANDIDATES	SELECTION RATIONALE
STATIC INVERTERS 400 HZ 115 VAC	3φ APOLLO - 1250 VA 1φ L-1011 – 750 VA 3φ PAX RIVER-750 VA **3φ MOD L-1011-2250 VA**	LARGE VA MODULE DESIRED, PARTICULARLY WITH NO PARALLEL OPERATION CAPABILITY. SIGNIFICANT 3φ POWER REQUIREMENTS. PHASE LOAD UNBALANCE NOT A PROBLEM.
TRANSFORMER RECTIFIERS 28V	LARGE NUMBER OF AIRCRAFT AIR-COOLED DESIGNS **200 AMP P-3C DESIGN**	LOW WEIGHT (18 LBs) AND BUILT TO MILITARY SPECIFICATIONS
REMOTE CONTROL CIRCUIT BREAKERS	NONE **SOLID STATE** HYBRID ELECTROMECHANICAL	EXISTING DESIGN WILL SAVE WEIGHT FOR DISTRIBUTION UNITS LOCATED AFT

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ELECTRICAL POWER SYSTEM REDUNDANCY

ITEM	NO. REQ'D FAIL SAFE	NO. SELECTED	RATIONALE
FUEL CELLS (8 KW)	3	4	LOWEST RELIABILITY UNIT IN EPS AND HIGHEST RISK OF CURTAILED MISSION – LIMITED DATA
3ϕ STATIC INVERTERS (CENTRAL) – 2250 VA	5	6	FO/FS SOURCE OF INVERTER AC POWER DESIRABLE
AC GENERATORS AND GCUs – 40 KVA	2	3	3 APUs AVAILABLE – COST FOR FO/FS NOT SIGNIFICANT
TRANSFORMER RECTIFIERS (200 AMPS) (HORIZONTAL AND FERRY FLIGHT ONLY)	4	5	FO/FS SOURCE OF DC POWER DESIRABLE
AC AND DC BUSES	2	2	TWO BUSES PROVIDE HIGH RELIABILITY

BACKUP POWER SYSTEM FOR FCS

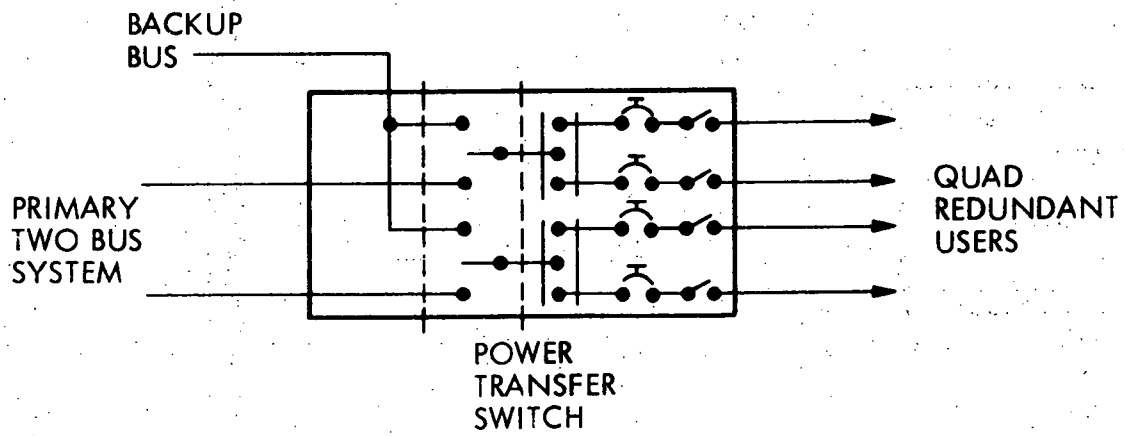
TIME PERIOD	ENERGY	CANDIDATE SOURCES/WT		
		NI-CD BATT	AG-ZN BATT	APU/GENERATOR
RETROGRADE THROUGH LANDING	2575 WATT-HR	260 LB	52 LB	31 LB N_2H_4 15 LB TANKAGE

BACKUP ELECTRICAL POWER SOURCE ONLY

- ALL NONESSENTIAL LOADS DROPPED
- EXISTING BUSING AND POWER CONDITIONING USED

BACKUP ELECTRICAL POWER SOURCE, BUSING AND AC INVERTER

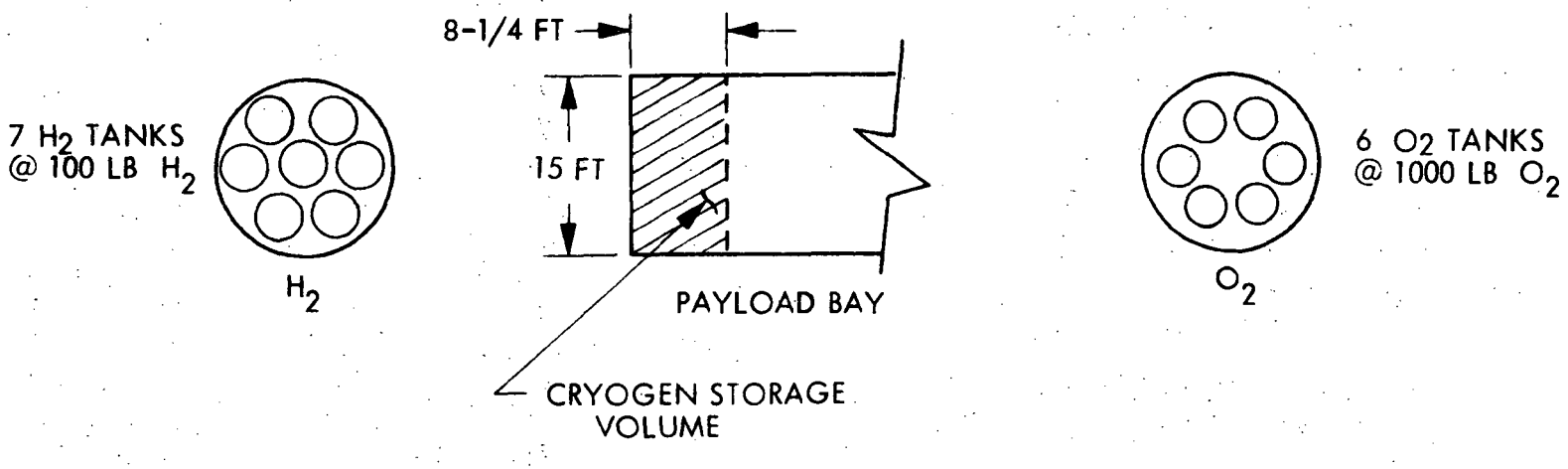
MAXIMUM 1 PHASE AC: 1506 VA, INVERTER WT 36 LB



PAYLOAD/ORBITER INTERFACE [illegible]

REFERENCE	MISSION TYPE	MISSION DURATION	AVG POWER
NSO-1, 2, 3, 4	SORTIE	2 WKS	10 KW
NSO-5	PALLET TYPE MODULE	2 WKS	10 KW

MISSION DURATION	PAYLOAD AVG POWER	ENERGY	REACTANT WEIGHT
30 DAYS	10 KW	7200 KW-HRS	6,110 LB



GN&C BASELINE COMPLIANCE

TD 3009 PARA NO.	REQUIREMENT	IN LMSC I NOV BASELINE	ACTION TAKEN OR REQUIRED
6.3	FLY-BY-WIRE AERO FLIGHT CONTROL WITH DEDICATED COMPUTER	YES	**COMPLETED – RECOMMEND ANALOG**
6.4	FLY-BY-WIRE SPACECRAFT FLIGHT CONTROL WITH DEDICATED DIGITAL COMPUTER	YES	**STUDY REDUNDANCY ASPECTS – IN PROCESS**
6.5	PHASED INSTALLATION OF AUTO-LAND AT MOST ECONOMICAL TIME	YES	**INCORPORATED ON EARLY HORIZONTAL FLIGHT**
6.6	RENDEZVOUS NAVIGATION CAPABILITY WITH COOPERATIVE TARGET OUT TO 300 NM	200 NM MAX CAPABILITY	CHANGED RENDEZVOUS SENSOR FROM PRECISION RANGING SYSTEM TO APOLLO VHF RANGING AND ADD-ON RANGE RATE UNIT
6.16	DETERMINE REDUNDANCY LEVELS WITH CONSIDERATION OF CRITICALITY, EXPERIENCE, AND COST FACTORS	PARTIAL	REDUNDACY CRITERIA ESTABLISHED; COST EFFECTIVENESS COMPUTER PROGRAM NOW BEING IMPLEMENTED

ORBITER SPACECRAFT GN & C SYSTEM

KEY REQUIREMENTS IMPLEMENTATION

REQUIREMENT	IMPLEMENTATION
ALL AZIMUTH LAUNCH, VERTICAL AND HORIZONTAL	ALL ATTITUDE GN&C SYSTEM
ASCENT GUIDANCE AND CONTROL	INERTIAL GUIDANCE USING IMU, CONTROL USING TVC. MANUAL CONTROL PROVIDED.
IN-FLIGHT TARGETING FOR ALL ΔV MANEUVERS	DIGITAL COMPUTER TO COMPUTE REFERENCE TRAJECTORY FROM CREW AND GROUND NAVIGATION INPUTS
IN-FLIGHT IMU ALIGNMENT	STAR TRACKER
RENDEZVOUS WITH COOPERATIVE TARGET	VHF RANGING USED FOR NAVIGATION AND GUIDANCE
AUTOMATIC AND MANUAL ORBIT VEHICLE STABILIZATION, CONTROL, AND TRANSLATION	HAND CONTROLLERS FOR TRANSLATION AND STABILIZATION INTERFACE DIRECTLY TO ACPS LOGIC AND ELECTRONICS. OVERRIDES AUTOPILOT ACPS CONTROL WHEN USED.

ORBITER GN & C (CONT)

KEY REQUIREMENTS IMPLEMENTATION

REQUIREMENT	IMPLEMENTATION
GUIDANCE AND STEERING TO SHAPE TRAJECTORY TO ENTRY VEHICLE HEATING CONSTRAINTS, PRESCRIBED g LIMITS AND TERMINAL FOOTPRINTS	UPDATE PRIOR TO DEORBIT, CLOSED LOOP CONTROL FROM INERTIAL GUIDANCE DURING REENTRY, VERTICAL CHANNEL UPDATE POST BLACKOUT
AUTOMATIC GUIDANCE AND NAV CAPABILITY PRIOR TO FINAL APPROACH	TACAN, RADAR ALTIMETER, AUTOPILOT, AIR DATA, AUTOTHROTTLE, INERTIAL NAV BACKUP
APPROACH AND LANDING NAVIGATION THROUGH GROUND AIDS OR BY INERTIAL UPDATING	SCANNING BEAM ILS, (MICROWAVE) IMU AND RADAR ALTIMETER BACKUP
LANDING AND HANDLING TO REQUIRE NO MORE SKILLS THAN OPERATIONAL LAND-BASED AIRCRAFT	USE OF CONTROL STICKS, CONVENTIONAL AIRCRAFT-TYPE PEDALS, STABILITY AUGMENTATION, CONTROL LAW MANAGEMENT, APPROACH AND LANDING AIDS AND INDICATORS
AUTOMATIC-CONTROLLED INSTRUMENT LANDING WITH PILOT-CONTROLLED INSTRUMENT LANDING AND PILOT-CONTROLLED VISUAL LANDING AS BACKUP	DUAL L-1011 AUTOPILOT, AIR DATA, AUTOTHROTTLE, AUTOSPEED-BRAKE CONTROL, MICROWAVE ILS. MANUAL CONTROL ALSO PROVIDED.

MAJOR CHANGES TO LMSC BASELINE GN&C

ORBIT NAVIGATION

DELETE AUTONOMOUS NAVIGATION CAPABILITY; DELETE HORIZON SENSOR AND ORBIT ALTIMETER; REDUCE LOAD ON GN&C COMPUTER

PROVIDE FOR NAVIGATION UPDATE THROUGH S-BAND DATA LINK

RENDEZVOUS RANGE AND RANGE RATE

DELETE PRECISION RANGING SYSTEM (CUBIC-CR100)

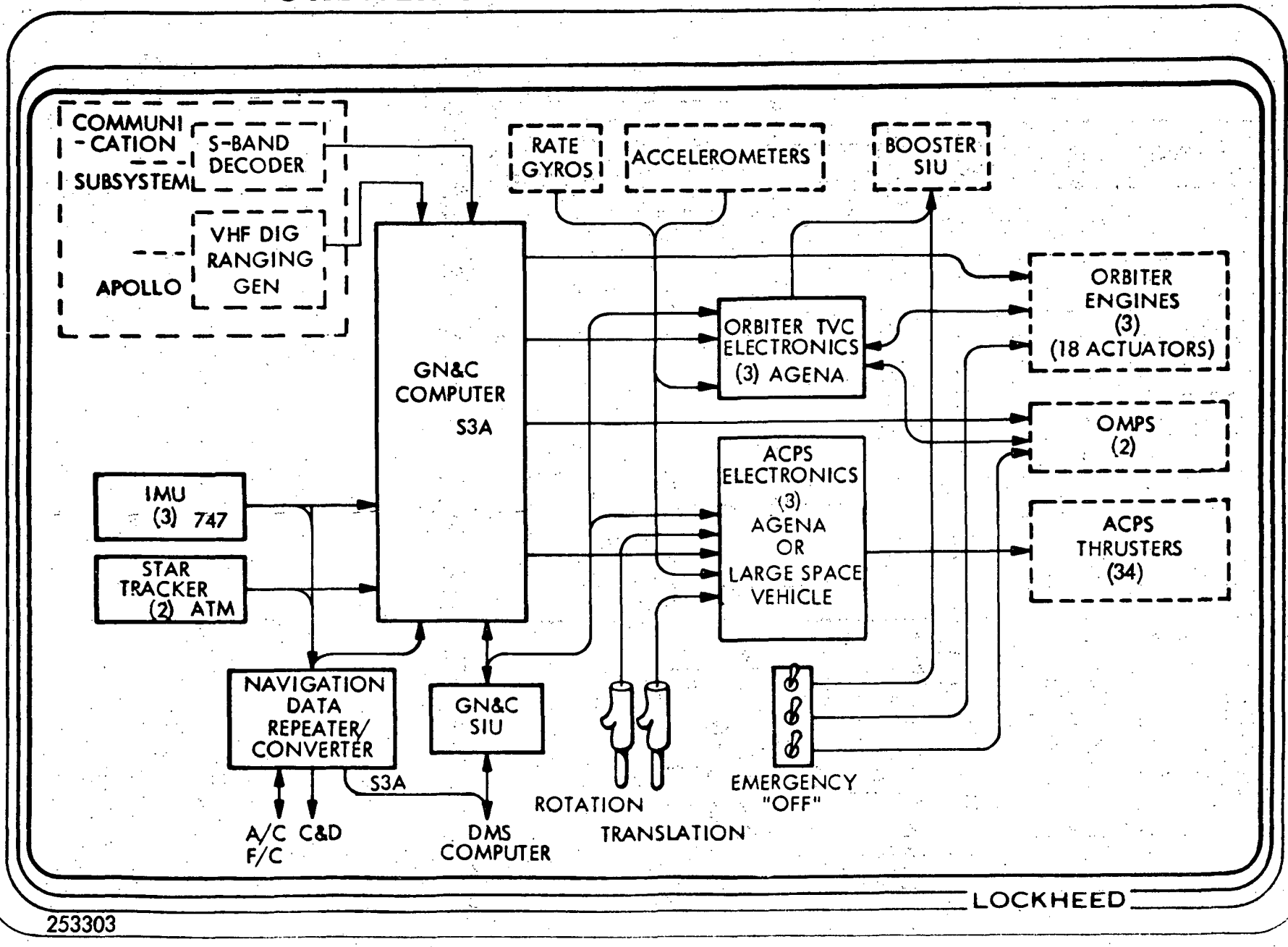
ADD

- VHF TRANSMITTER/RECEIVER (APOLLO)
- DIGITAL RANGING GENERATOR (APOLLO)
- RANGING TONE TRANSFER ASSEMBLY (APOLLO)
- RANGE RATE UNIT

INERTIAL MEASUREMENT UNIT

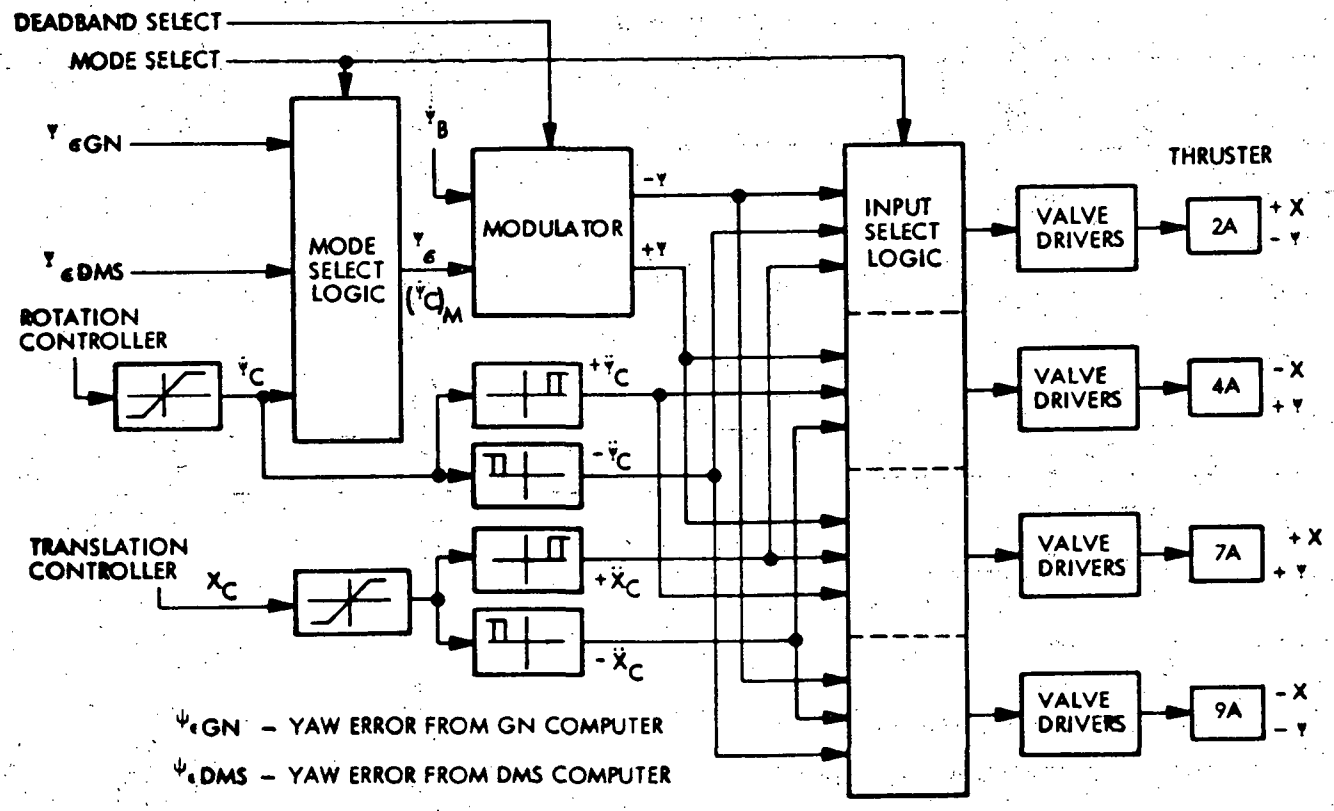
CHANGE FROM 3 PLATFORMS **(CAROUSEL IV)** TO 3 TRIAD STRAPDOWN WITH ROTATED SENSORS (HONEYWELL ISA)

ORBITER SPACECRAFT GN&C SYSTEM



TYPICAL ACPS DRIVE ELECTRONICS

(X TRANSLATION AND YAW ROTATION)



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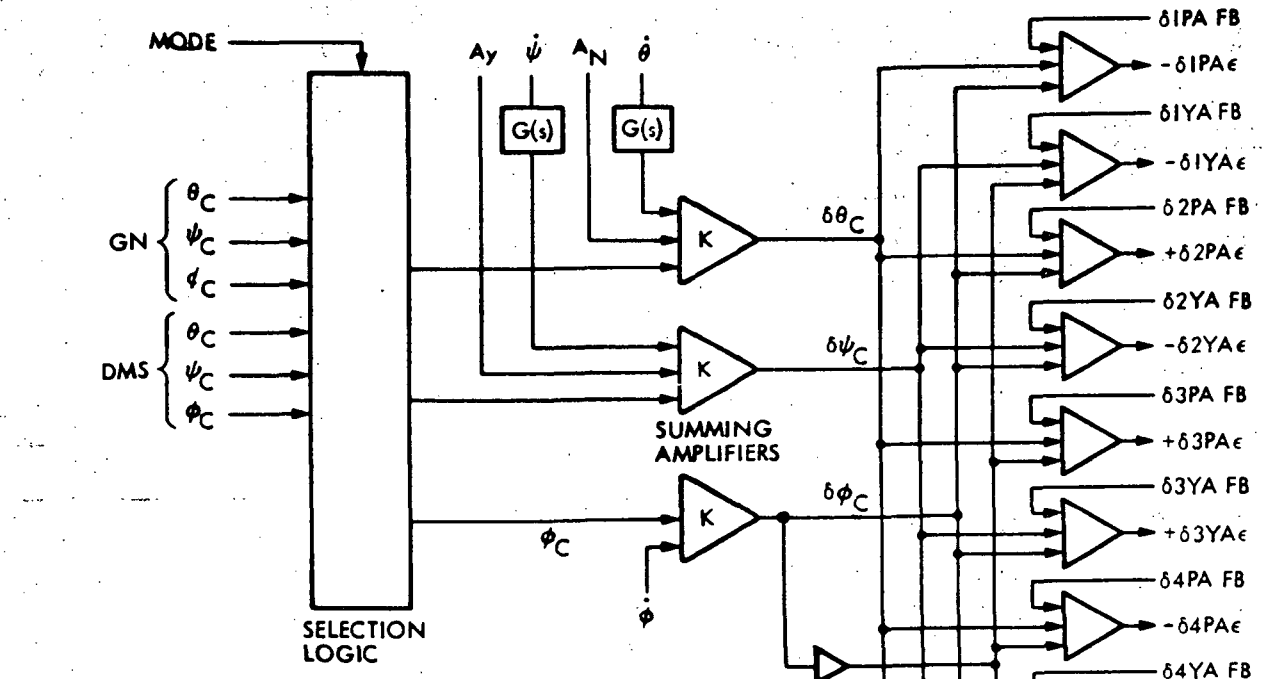
ORBITER TVC ELECTRONICS



GN – GUIDANCE AND NAVIGATION COMPUTER
DMS – DATA MANAGEMENT SYSTEM COMPUTER
δ1PAε – ERROR (ε) SIGNAL (δ) TO PITCH AXIS (P) ACTUATOR "A" (A) ON ENGINE "1" (1)
Y – YAW AXIS
FB – FEEDBACK
A_Y, A_N – LATERAL, NORMAL ACCELERATION

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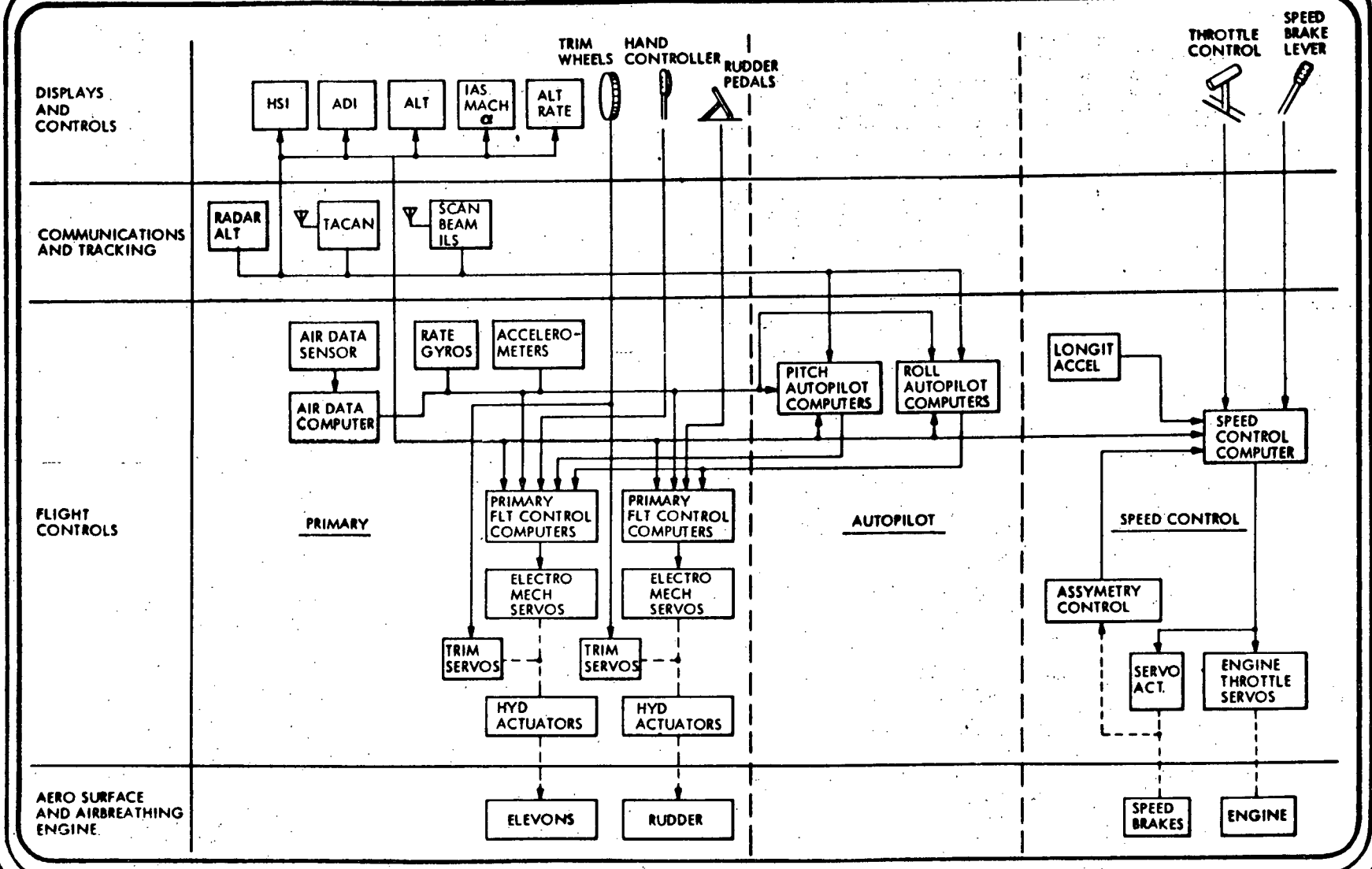
ORBITER AERO FLIGHT CONTROL SYSTEM



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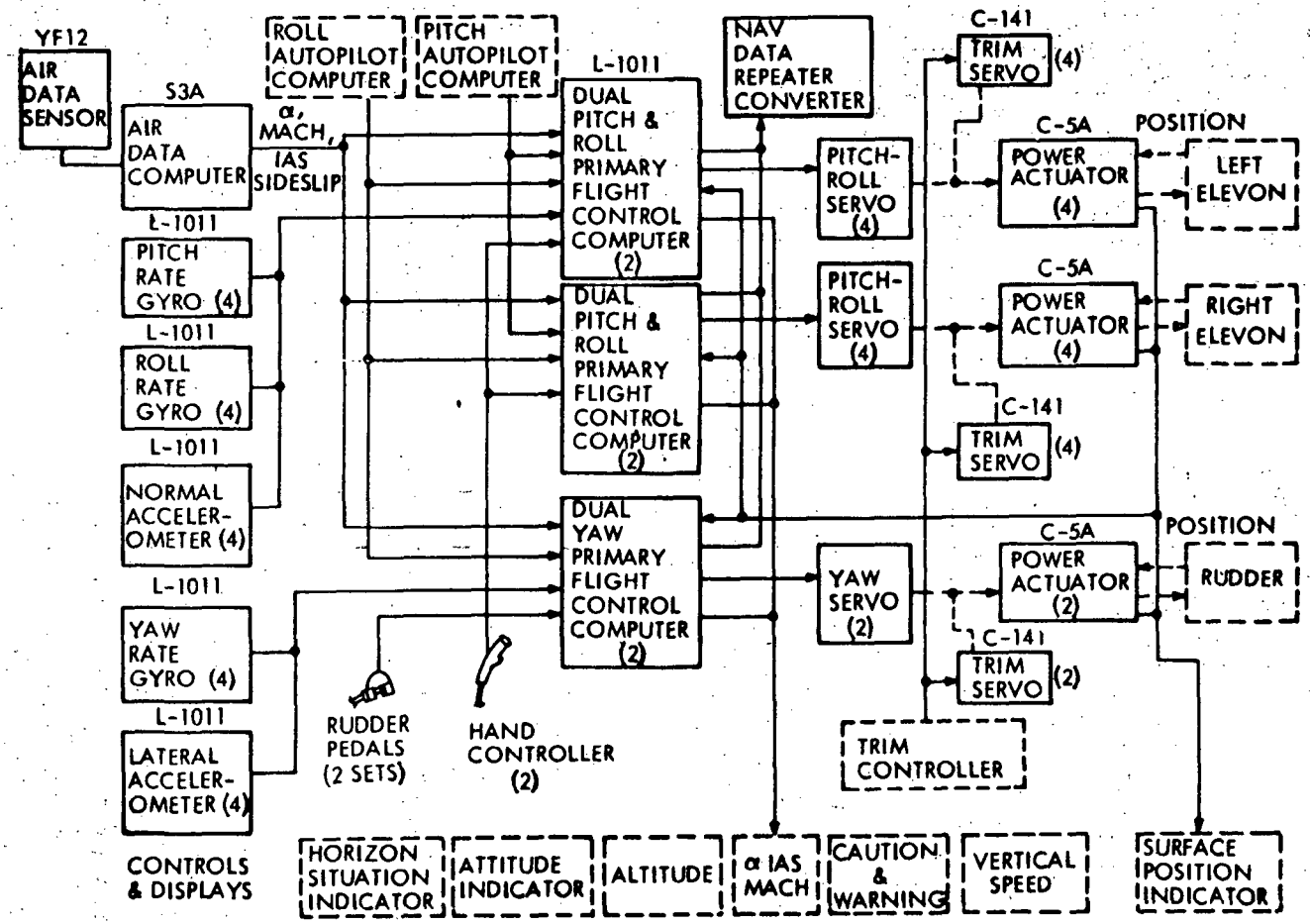
ORBITER PRIMARY FLIGHT CONTROL SYSTEM



DO6420(1) * SPLIT RUDDER WITH 1 LEVEL REDUNDANCY ON EACH
233209 NOW UNDER INVESTIGATION

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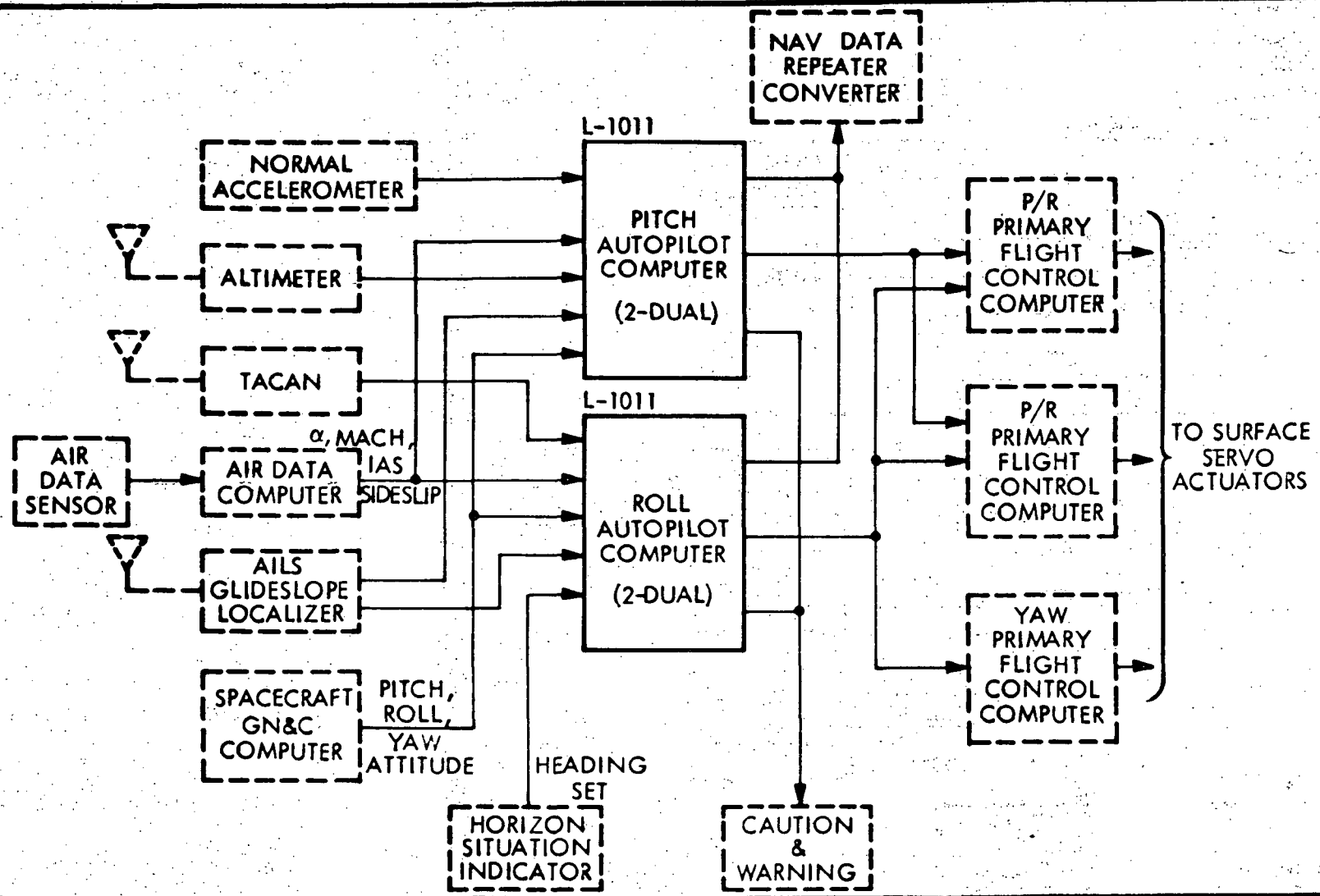
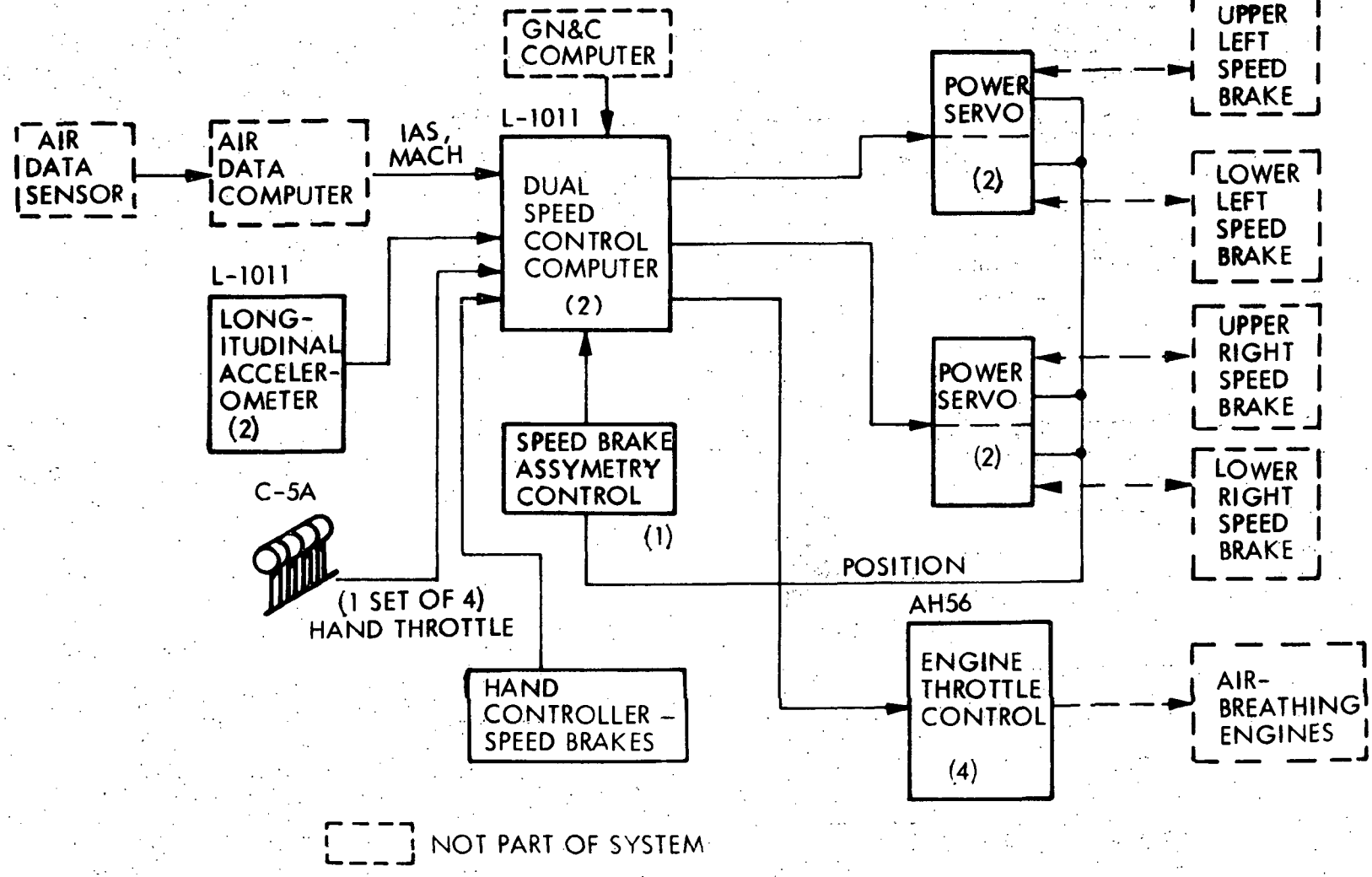
ORBITER AUTOPILOT SYSTEM



ORBITER AUTOMATIC SPEED CONTROL



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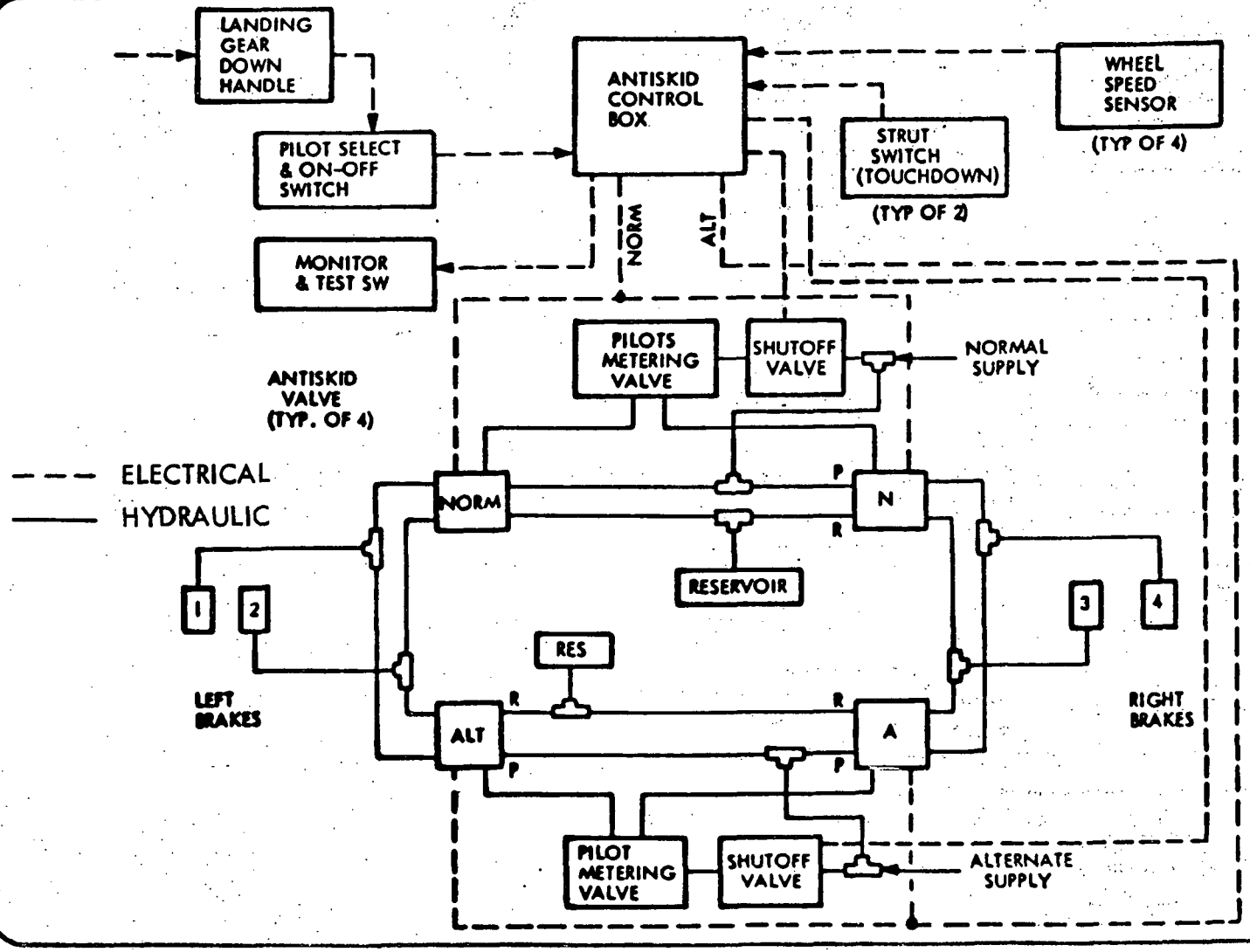
FLIGHT CONTROL SYSTEM

BRAKES AND ANTISKID SYSTEM



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AUTOLAND IMPLEMENTATION

FLIGHT-PROVEN L-1011 CONCEPTS

CONTROL LAWS – BASIC FUNCTIONS SAME
REDUNDANCY AND MONITORING
FULL MODE ANNUNCIATION

FLIGHT-PROVEN L-1011 HARDWARE

PACKAGING DESIGN
CIRCUIT DESIGN
PARTS SELECTION
MATERIAL SELECTION
MANUFACTURING PROCESSES, TECHNIQUES
AUTOMATIC TEST EQUIPMENT AND PROCEDURES

FAIL-OPERATIONAL/FAIL-SAFE OPERATION

- UNDERGOING CERTIFICATION FOR CAT III LANDING
  - FLIGHT TEST
  - COMPUTER AND IRON BIRD SIMULATION
- DUAL-DUAL REDUNDANCY

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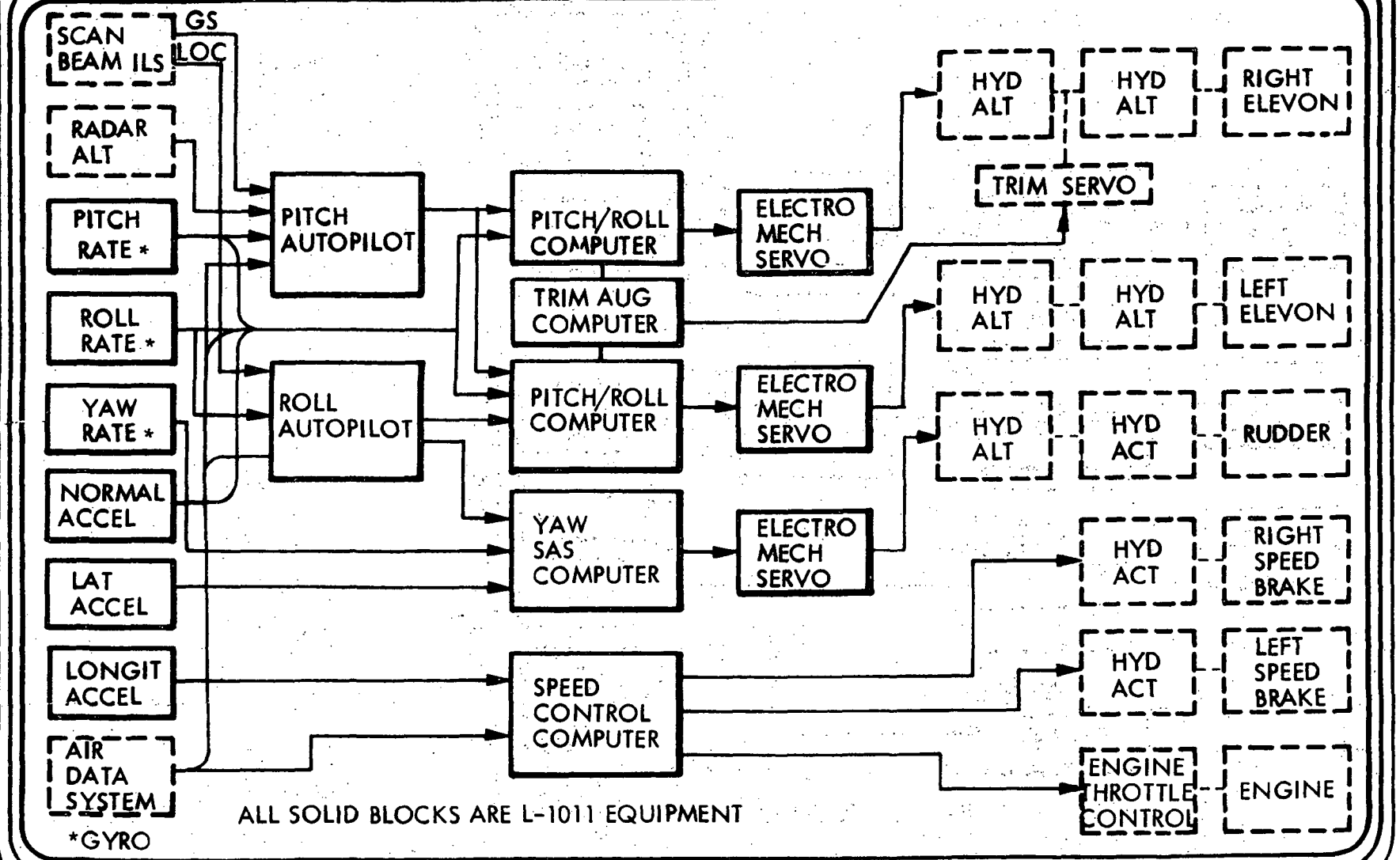
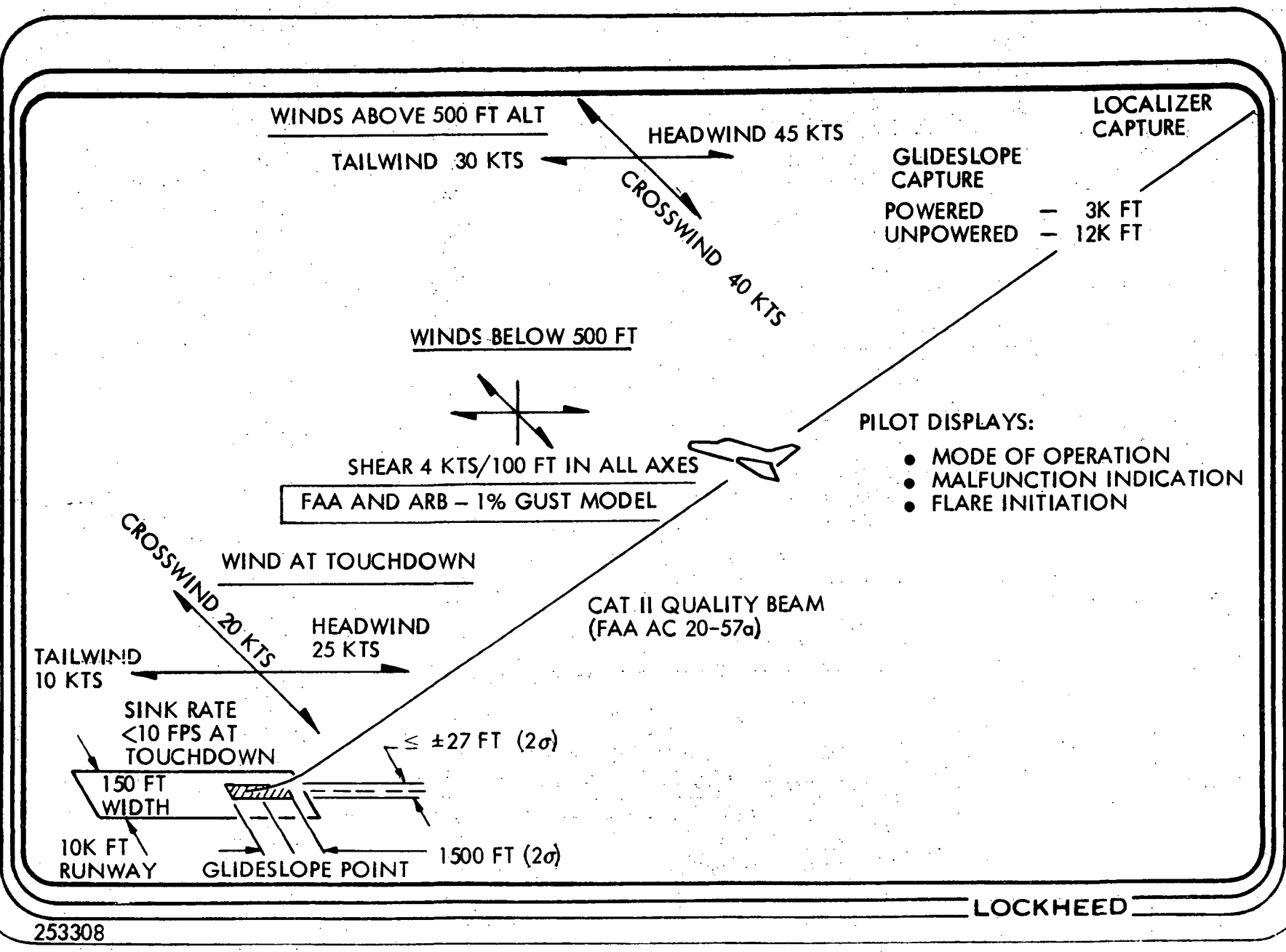
EQUIPMENT REQUIRED FOR AUTOLAND



ORBITER AUTOLAND SIMULATION REQUIREMENTS



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ORBITER AUTOLAND SIMULATION

PARAMETER	2σ (95.5%) PROBABILITY LEVEL (1)	LIMIT	PROBABILITY OF EXCEEDING LIMIT
DESCENT RATE AT TOUCHDOWN	1.1–5.6 FPS	10 FPS LANDING GEAR STRUCTURE	5×10^{-8}
TOUCHDOWN RANGE DISPERSION	200 FT BEFORE G.S. INTERCEPT TO 900 FT AFTER	940 FT BEFORE GLIDE SLOPE INTERCEPT (MIN) 2700 FT BEYOND G.S. INTERCEPT (MAX)	10^{-7}
PITCH ATTITUDE AT TOUCHDOWN	12–16.6 DEG	17 DEG TAILSCRAPE	3×10^{-2}

(1) RESULT OF 1000 COMPUTER RUNS

LIMITING DISTURBANCES: (PROBABILITY OF EXCEEDING = 10^{-2})

6.35	FPS	(RMS)	HORIZONTAL WIND GUSTS
3.2	FPS	(RMS)	VERTICAL WIND GUSTS
10	μa	(RMS)	BEAM NOISE

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OPERATIONAL AUTOLAND INSTALLATION TIMING

ALTERNATIVES

- FIRST (OR EARLY) HORIZONTAL FLIGHT
- FIRST OPERATIONAL VERTICAL FLIGHT
- LATER IN THE PROGRAM

TEST FLIGHTS REQUIRED BEFORE BECOMING FULLY OPERATIONAL

ISSUES

PEAK FUNDING REDUCED FOR LATER INSTALLATION – INSTALLATION COST IS $1M–$3M

TOTAL PROGRAM COSTS REDUCED IF ALL GN&C SYSTEMS INCLUDING AUTOLAND INCORPORATED AND TESTED AT SAME TIME

- SEPARATE FLIGHTS TO TEST AUTOLAND ALONE NOT NEEDED
- NO SPECIAL AUTOLAND FLIGHT TEST VEHICLE REQUIRED
- LATER INSTALLATION MAY CAUSE "SCAR" PROBLEMS

L-1011 EXPERIENCE WILL MINIMIZE DEVELOPMENT TIME – COMPATIBLE WITH EARLY INSTALLATION EVEN IF STARTED 1 YEAR AFTER SHUTTLE PROGRAM GO-AHEAD

SAFETY ENHANCED THROUGH USE OF AUTOLAND

- TOUCHDOWN DISPERSIONS REDUCED
- PILOT WORKLOAD REDUCED
- L-1011 TEST FLIGHTS DEMONSTRATE CONSISTENTLY LOW IMPACT LANDING WITH AUTOLAND COMPARED TO MANUAL

AUTOLAND REQUIRED FOR UNMANNED OPERATION

RECOMMENDATION

INCORPORATE IN FIRST HORIZONTAL FLIGHT

- PEAK FUNDING IMPACT SMALL
- EARLY INCORPORATION REDUCES PROGRAM COST AND RISKS

ORBITER GN&C EQUIPMENT

EQUIPMENT	PART NO.	WEIGHT PER EACH	PRESENT OR PLANNED USAGE	QUANTITY/EFFECTIVITY			
				FHF	FVFM	FVFUN	OPER
INERTIAL REFERENCE UNIT	CAROUSEL IV CAROUSEL VB OR HONEYWELL 448	53 LB 58 LB 38 LB	747 TIIIC AGENA		2	2	3
DIGITAL COMPUTER*	UNIVAC 1832	126 LB	S-3A		1	1	1
STAR TRACKER	BENDIX ATM OR ITT MMOS	77 LB	SKYLAB				2
MAIN ENGINE GIMBAL SERVO (TVC) ACTUATOR PKG	MOOG	50 LB	SIVB		8	8	8

* DMS COMPUTER BACKS UP GN&C COMPUTER

ORBITER GN&C EQUIPMENT (CONT)

EQUIPMENT	PART NO.	WEIGHT PER EACH	PRESENT OR PLANNED USAGE	QUANTITY/EFFECTIVITY			
				FHF	FVFM	FVFUN	OPER
TVC ELECTRONICS	SIMILAR TO AGENA P110 TVC ELECTRONICS	30 LB	AGENA		3 (8 CHANNELS EACH)	3	3
ACPS ELECTRONICS	SIMILAR TO AF P467 ACPS ELECTRONICS	50 LB	AF P467		3 (EACH HAS DRIVERS FOR 12 ENGINES)	3	3
SUBSYSTEM INTERFACE UNITS	—	55 LB	NEW		3	3	3
S-BAND DATA LINK**			APOLLO	2	2	2	2
VHF RANGING**			APOLLO				2
TOTAL				2	22	22	27

** PART OF COMMUNICATION SUBSYSTEM

ORBITER AERO NAVIGATION AND FLIGHT CONTROL EQUIPMENT

EQUIPMENT	PART NO.	WEIGHT PER EACH (LB)	PRESENT OR PLANNED USAGE	QUANTITY/EFFECTIVITY			
				FHF	FVFM	FVUM	OPER
RATE GYRO	672300	2	L1011	12	12	12	12
ACCELEROMETER	672301, 2	1	L1011	10	10	10	10
AUTOPILOT COMPUTER	672314, 5	28	L1011	4	4	4	4
SPEED BRAKE SERVO	NEW	10	NEW	4	4	4	4
ENGINE SPEED CONTROLLER	C1033	15	AH56	-	4	4	4
SPEED CONTROL COMPUTER	672294	27	L1011	2	2	2	2
ANTISKID AND TOUCHDOWN SYSTEM	NEW	30	NEW	1	1	1	1
*TACAN TRANCEIVER/ ANTENNA	ARN84	37/6	S3A	2/4	2/4	2/4	2/4
*ILS RECEIVER/ANTENNA	ILS-70	10/6	C5A	2/4	-	-	-
*SCANNING BEAM ILS RECEIVER/ANTENNA	NEW	15/5	NEW	-	2/4	2/4	2/4
*RADAR ALT/ANTENNA	APN-201	10/1	S3A	2/4	2/4	2/4	2/4

*PART OF COMMUNICATION SUBSYSTEM

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ORBITER AERO NAV & FLIGHT CONTROL EQUIP (CONT)

EQUIPMENT	PART NO.	WEIGHT PER EACH (LB)	PRESENT OR PLANNED USAGE	QUANTITY/EFFECTIVITY			
				FHF	FVFM	FVUM	OPER
COMPASS COUPLER	2591201	9	C5A	2	-	-	-
COMPASS CONTROLLER	2594911	1	C5A	2	-	-	-
FLUX VALVE	2575570	1	C5A	2	-	-	-
MAGNETIC COMPENSATOR	2591200	1	C5A	2	-	-	-
DIRECTIONAL GYRO	2594401	15	C5A	2	-	-	-
VERTICAL GYRO	2593742	15	C5A	2	-	-	-
RUDDER SERVO	4Y91577	48	C5A	2	2	2	2
ELEVON SERVO	4Y91013	48	C5A	8	8	8	8
PFCS SERVO	697660	5	STOL	10	10	10	10
TRIM/BACKUP SERVO	544268	1	C141	10	10	10	10
PFCS COMPUTER	672293	23	L1011	6	6	6	6
AIR DATA SENSOR		29	YF-12	2	2	2	2
AIR DATA COMPUTER	A/N-5		S-3A	2	2	2	2

REDUNDANCY SELECTION CRITERIA

SELECT REDUNDANCY CONFIGURATION BASED ON SYSEFF* PROGRAM USING AS CONSTRAINTS

- POINT OF DIMINISHING RELIABILITY RETURN
- MINIMUM EFFECTIVE PROGRAM COST
- MAXIMUM ALLOWABLE WEIGHT
- MAXIMUM ALLOWABLE SUBSYSTEM COST

EACH CREW SAFETY FUNCTION OR EQUIPMENT MUST HAVE AT LEAST FAIL-OP CAPABILITY; MATCH SYSEFF SELECTED CONFIGURATION AGAINST FAIL-OP AND ADD REDUNDANCY, IF REQUIRED

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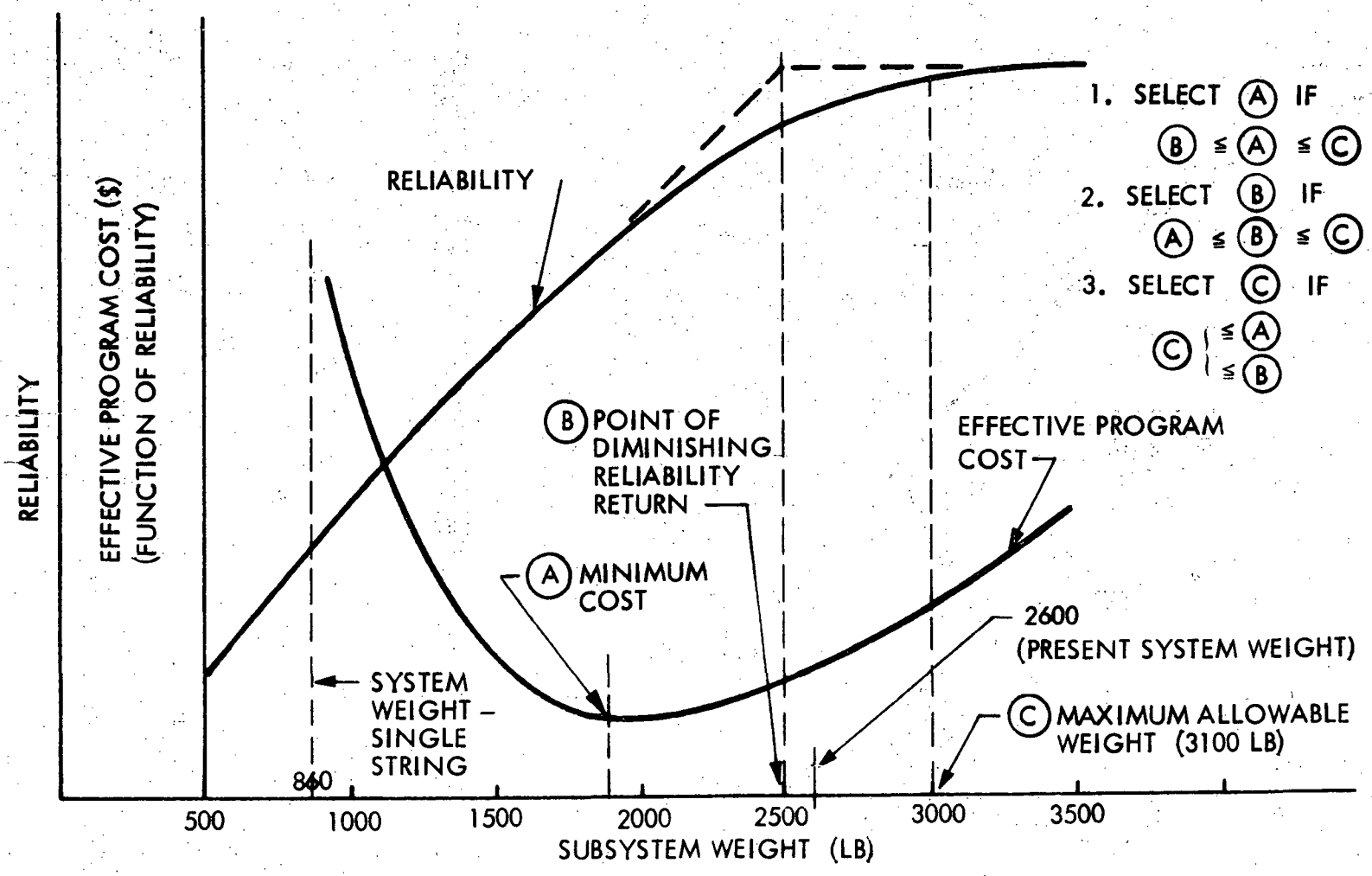
*SYSTEM EFFECTIVENESS

CHARACTERISTICS OF SYSEFF PROGRAM OUTPUTS



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ORBITER CONTROL BLENDING STUDY

TASK	ISSUE	CONSTRAINTS
SELECT BEST CONTROL SYSTEM CONCEPT FOR BLENDING AND TRANSITION	SPACECRAFT/AIRCRAFT SYSTEM SIGNAL INTERFACES	MAXIMUM ALLOWABLE CONTROL SURFACE TEMPERATURE
	ACPS PROPELLANT REQUIREMENTS	MAXIMUM AVAILABLE ACPS TORQUE
	CONTROL AUTHORITY REQUIREMENTS	MAXIMUM ALLOWABLE YAW AND ROLL CONTROL DEADBANDS
	REQUIRED SURFACE DEFLECTIONS FOR HIGH-ALTITUDE TRANSITION	RUDDER CONTROL EFFECTIVENESS AT HIGH α
SELECT BEST CONTROL SYSTEM LOGIC	COMPATIBILITY WITH MANUAL CONTROL CONCEPTS	NO PROVEN HYPERSONIC AIR DATA SYSTEMS AVAILABLE
	SUSCEPTIBILITY TO FALSE COMMANDS DUE TO FAILURE	MAXIMUM EXPECTED ERRORS FROM IMU DUE TO SIDE WINDS
	SENSOR REQUIREMENTS	
	GN&C COMPUTATION REQUIREMENTS	

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ORBITER CONTROL BLENDING CONCEPTS

ALTERNATES	ADVANTAGES	DISADVANTAGES
CONCEPT 1: SUPERSONIC PITCH/ROLL BLENDING PRIOR TO PITCH HIGH-TO-LOW α TRANSITION	HIGH PITCH/ROLL CONTROL AUTHORITY DURING TRANSITION MAXIMUM ELEVON DEFLECTION NOT LIMITED BY AERODYNAMIC HEATING	SEPARATE YAW AXIS TRANSITION ACPS PROPELLANT CONSUMPTION NOT MINIMIZED AERO GAIN SCHEDULING REQUIRED FOR SUPERSONIC HIGH AND LOW α AND TRANSONIC/SUBSONIC LOW α FLIGHT
CONCEPT 2: HYPERSONIC PITCH/ROLL BLENDING	HIGH PITCH/ROLL CONTROL AUTHORITY DURING TRANSITION POTENTIAL OF MINIMIZING PROPELLANT CONSUMPTION WITHIN HEATING CONSTRAINT	SEPARATE YAW AXIS TRANSITION SURFACE DEFLECTION LIMITED BY HEATING CONSTRAINTS AERO GAIN SCHEDULING REQUIRED • SUPERSONIC HIGH AND LOW α • TRANSONIC/SUBSONIC LOW α FLIGHT
CONCEPT 3: SIMULTANEOUS PITCH/ROLL/YAW BLENDING AFTER PITCH HIGH-TO-LOW α TRANSITION	SIMULTANEOUS SWITCHOVER AERO GAIN SCHEDULING REQUIRED ONLY FOR LOW α FLIGHT (SUPERSONIC, TRANSONIC, SUBSONIC)	HIGHEST ACPS PROPELLANT CONSUMPTION LIMITED CONTROL AUTHORITY DURING HIGH DYNAMIC PRESSURE

ORBITER CONTROL BLENDING APPROACH

EVALUATION TECHNIQUE

SIX-DEGREE OF FREEDOM DIGITAL COMPUTER EVALUATION

INPUTS

TRAJECTORY	–	HIGH CROSSRANGE
COMMAND INPUT	–	BANK ANGLE AND ANGLE-OF-ATTACK PROFILES
DISTURBANCE	–	HIGH-ALTITUDE WIND SHEAR PROFILE
AERODYNAMIC CHARACTERISTICS	–	EXPECTED VARIATIONS OF C_{n_β}, C_{ℓ_β}

OUTPUTS

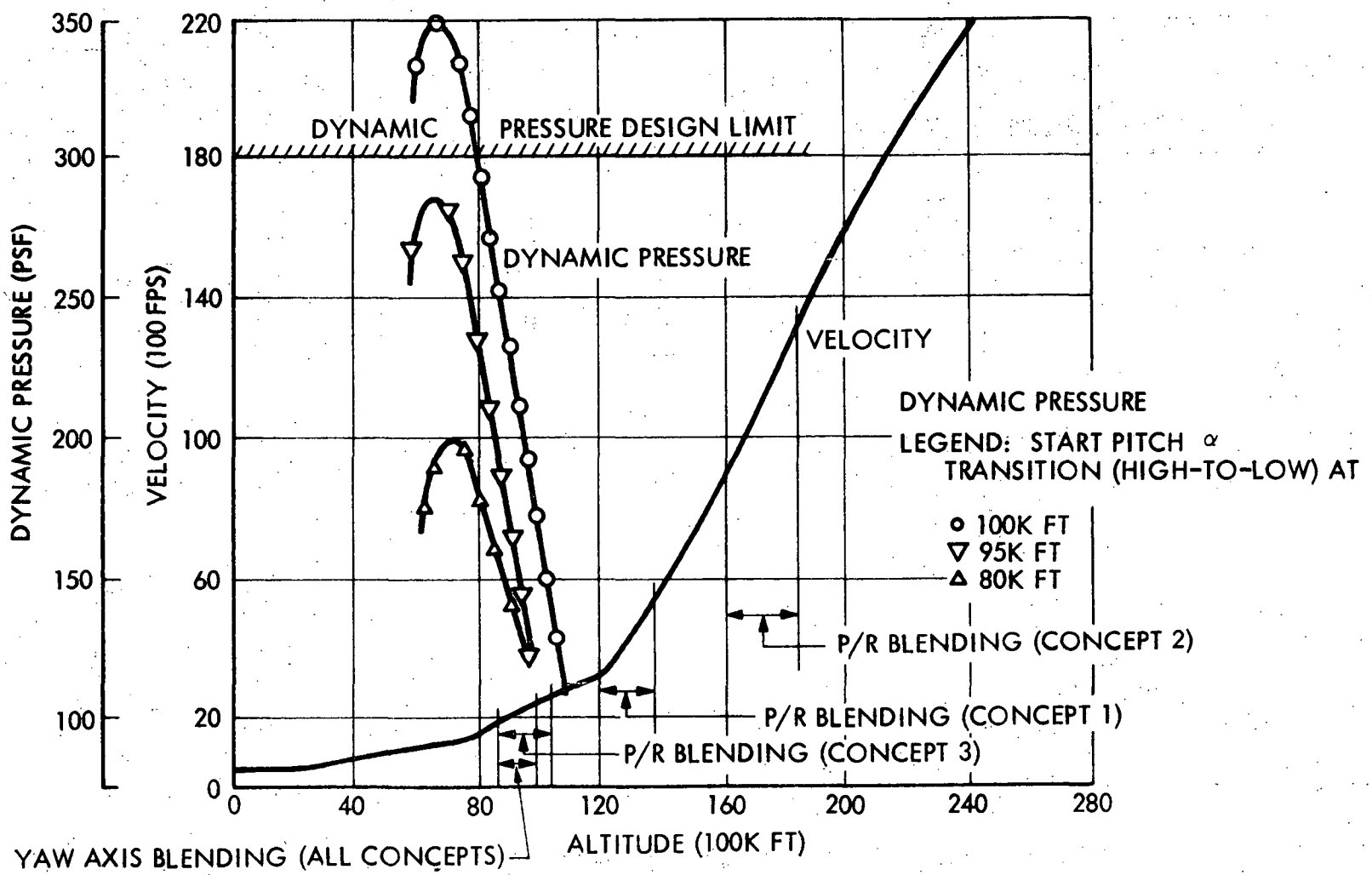
DEFINITION OF COMPUTATION LOGIC

EVALUATION OF DYNAMIC PERFORMANCE OF CONTROL SYSTEM

COMPARISON OF ACPS PROPELLANT REQUIREMENTS

EARLIEST FEASIBLE TRANSITION TO AERO CONTROL FOR PITCH AND ROLL

ORBITER CONTROL BLENDING -ALTITUDE & DYNAMIC PRESSURE



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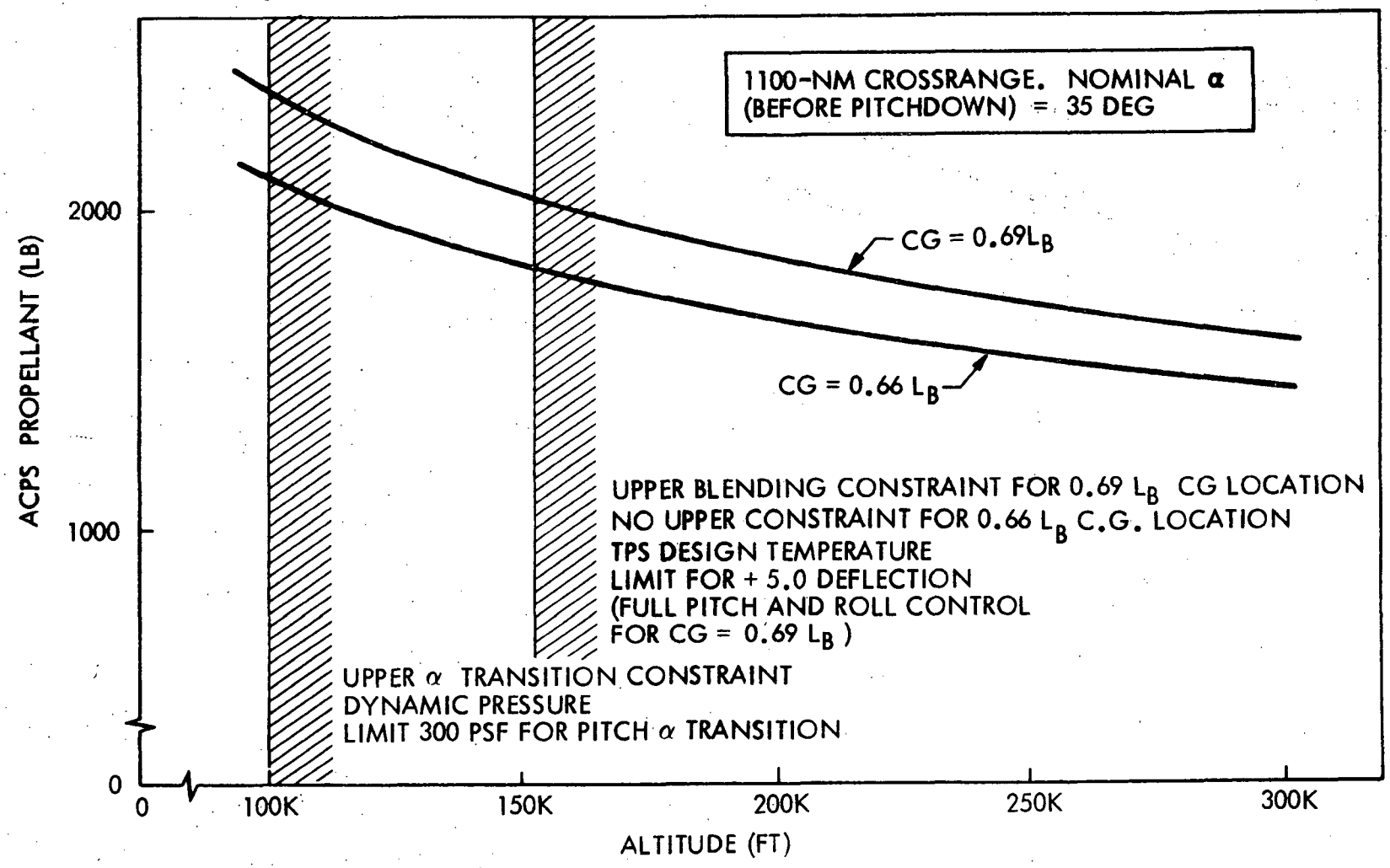
TRANSITION AND BLENDED CONTROL CONSTRAINTS

EFFECT OF BLENDING ALTITUDE ON PROPELLANT REQUIREMENTS O4OA



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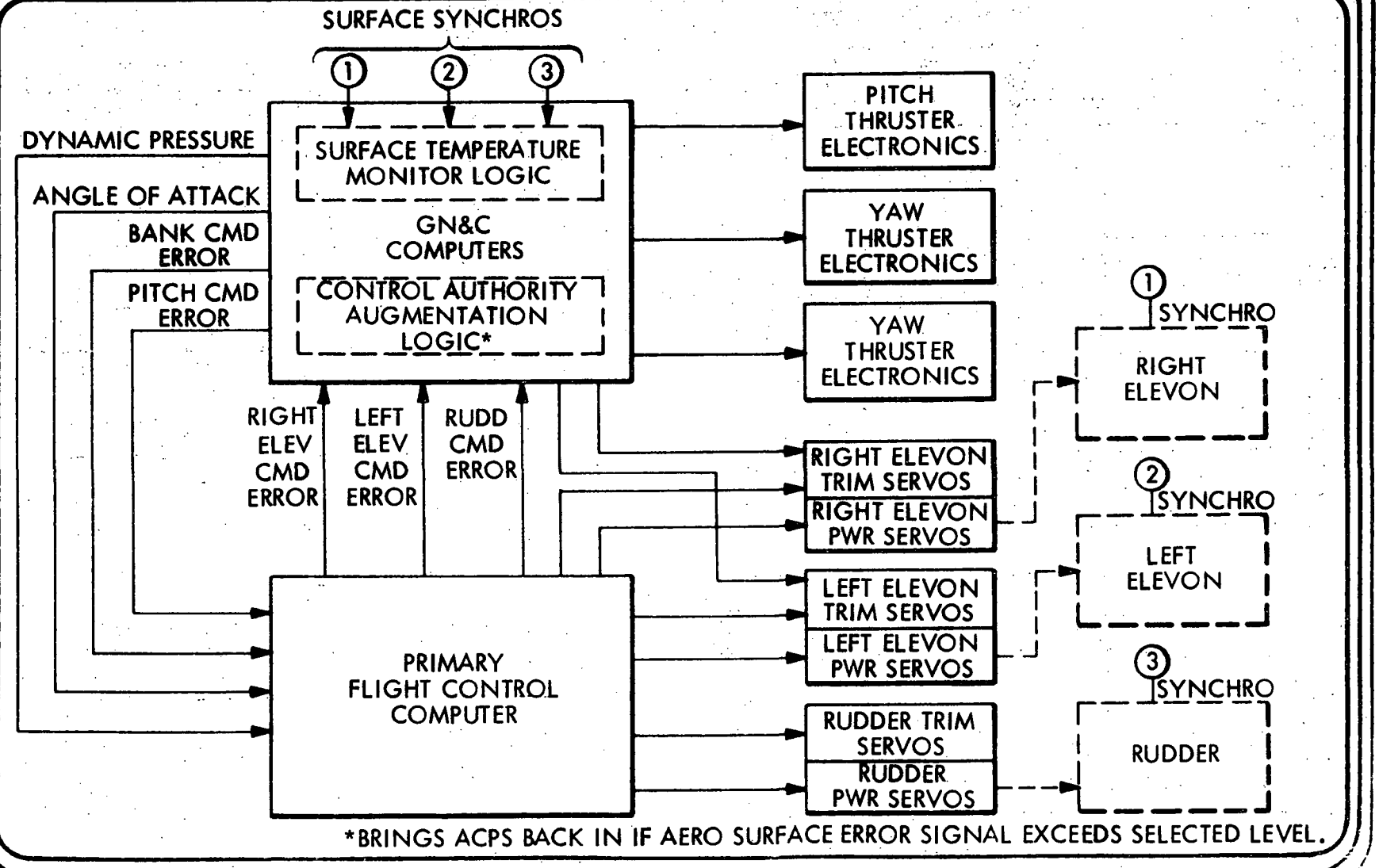
COMPUTER INTERFACE FOR BLENDING



*BRINGS ACPS BACK IN IF AERO SURFACE ERROR SIGNAL EXCEEDS SELECTED LEVEL.

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AEROFLIGHT CONTROL COMPARISON

ANALOG VS DIGITAL

PARAMETER	DIGITAL (4 UNITS)	ANALOG (12 DUAL UNITS)
DEVELOPMENT COSTS	$900K (6K WORDS)	$501K (50% REDESIGN SAS; 15% REDESIGN A/P; 7% REDESIGN SPEED CONTROL)
EQUIPMENT COSTS/VEHICLE	$300K	$130K
WEIGHT	100 LB	304 LB
POWER	480 WATTS	1840 WATTS
RELIABILITY (200 HR)	0.9962-0.9991	0.9922
FAILURE DETECTION	MAJORITY VOTING, LIMIT, LOOP, AND PARITY CHECKS	MAJORITY VOTING AND (WIDE) LIMIT CHECKS
FLEXIBILITY TO CHANGES	REPROGRAM	INCREMENTAL REDESIGN
DEVELOPMENT/PRODUCTION STATUS	IN DEVELOPMENT	IN PRODUCTION AND FLIGHT USE
CONFIDENCE FACTOR	LOW-LIMITED SIMULATION AND TEST	HIGH DUE TO L-1011 EXPERIENCE: • THOUSANDS OF SIMULATION HRS • THOUSANDS OF SYSTEM GROUND TEST HRS • HUNDREDS OF FLIGHT TEST HRS

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ANALOG vs DIGITAL AEROFLIGHT CONTROL

RECOMMENDATION AND RATIONALE

RECOMMENDATION – ANALOG FLIGHT CONTROL

RATIONALE

COST

- ANALOG DEVELOPMENT COST ≈ 1/2 DIGITAL
- ANALOG SHIP SET COST ≈ 1/2 DIGITAL

RISK – ANALOG SYSTEM IS MINIMUM RISK

- USES L-1011 CONTROL LAWS
- USES L-1011 HARDWARE MODIFICATION ≈ 7% ON SPEED CONTROL
  15% ON AUTO PILOT
  50% ON SAS
- CONCEPTS AND DESIGN WELL PROVEN THROUGH THOUSANDS OF HOURS OF SIMULATION, THOUSANDS OF HOURS OF GROUND TEST, AND HUNDREDS OF HOURS OF FLIGHT TEST
- SAME KEY DESIGN, ANALYSIS, AND PRODUCTION PERSONNEL ON L-1011 FC PROGRAM WILL BE USED ON SHUTTLE

IMU CANDIDATES

SYSTEM	ADVANTAGES	DISADVANTAGES
1 3 ORTHOGONAL TRIAD PLATFORMS	UNIT COST ONBOARD CALIBRATION SIMPLICITY	HIGHEST FAILURE RATE FAIL-OP ONLY - COULD USE DISSIMILAR SENSORS (E.G., STAR TRACKER TO GET FAIL-OP/FAIL-OP) NEEDS MAJOR MODIFICATIONS
2 2 ORTHOGONAL TRIAD PLATFORMS (1 SKEWED)	LOWEST SHIP SET COST ONBOARD CALIBRATION	DEGRADED ALIGNMENT OF SKEWED PLATFORM CROSS STRAP LOGIC TO INTERTORQUE PLATFORMS NEEDS MAJOR MODIFICATIONS
3 3 ORTHOGONAL TRIAD STRAPDOWN	SIMPLICITY OF PROCESSOR AND REDUNDANCY MANAGEMENT MINOR HARDWARE MODIFICATION	FAIL-OP ONLY - COULD USE DISSIMILAR SENSORS TO GET FAIL-OP/FAIL-OP NEEDS OPTICAL AZIMUTH ALIGNMENT (CLOSED LOOP SYSTEM) NEEDS AERO FLIGHT DEMONSTRATION

IMU CANDIDATES (CONT)

SYSTEM	ADVANTAGES	DISADVANTAGES
4 2 ORTHOGONAL TRIAD STRAPDOWN (1 SKEWED)	LOWEST SHIP SET WEIGHT MINOR HARDWARE MODIFICATION	TWO REFERENCE SURFACES REQUIRED (1 SKEWED) NEEDS OPTICAL AZIMUTH ALIGNMENT NEEDS AERO FLIGHT DEMONSTRATION
5 3 TRIAD STRAPDOWN (ROTATED SENSORS)	MINOR HARDWARE MODIFICATIONS INCREASED RELIABILITY CHOICE OF - INCREASED LAUNCH READINESS OR - REMOVE ONE GYRO AND ONE ACCEL FROM EACH TRIAD	THREE REFERENCE SURFACES REQUIRED (PERPENDICULAR) NEEDS OPTICAL AZIMUTH ALIGNMENT RISK ON SOFTWARE DEVELOPMENT NEEDS AERO FLIGHT DEMONSTRATION
6 1 - SIX GYRO STRAPDOWN (DODECAMEDRON)	INCREASED RELIABILITY MAINTAINABILITY - EACH SENSOR PACKAGED AND MOUNTED SEPARATELY	NOT IN PRODUCTION DEVELOPMENT RISK NEEDS AERO FLIGHT DEMONSTRATION

IMU CANDIDATE COMPARISON

	1 – 3 ORTH TRIAD PLATFORM	2 – 2 ORTH TRIAD PLATFORM (1 SKEWED)	3 – 3 ORTH TRIAD STRAPDOWN	4 – 2 ORTH TRIAD STRAPDOWN (1 SKEWED)	5 – 3 TRIAD STRAPDOWN (ROTATED SENSORS)	6 – HEXAD (DODECA-HEDRON)
IMUs PER SYSTEM	3	2	3	2	3	1
PERFORMANCE	BOTH PLATFORM AND STRAPDOWN PERFORMANCE MEET SHUTTLE REQUIREMENTS. PLATFORM SLIGHTLY BETTER					
RELIABILITY (NORMALIZED TO CONFIG 3 MTBF 1700 HR)	0.65	1.4	1.0	2.2	>2.2	2.2
WEIGHT (LB)	159	106	108	72	108	103
POWER (WATTS)	450	300	420	280	420	306
VOLUME (FT^3)	4.5	3.0	1.26	0.84	1.26	1.69
DEVELOPMENT STATUS	CAROUSEL IV DEVELOPED 1000 BUILT AND FLOWN NEED FULL QUAL TO SPACE ENVIRONMENT		DEVELOPED, QUALIFIED TO SPACE ENVIRONMENT 6 BUILT, 2 FLOWN			DESIGN 95% COMPL. NEED FULL QUAL

IMU CANDIDATE COMPARISON (CONT)

	CONFIGURATION					
	1	2	3	4	5	6
	• VIBRATION ISOLATORS • Z ACCEL OUTPUT • GIMBAL OUTPUT	• VIBRATION ISOLATORS • Z ACCEL OUTPUT • GIMAL OUTPUT • CROSS STRAP PLATFORMS	CHANGE ACCEL OUTPUT FORMAT	• CHANGE ACCEL OUTPUT FORMAT • CROSS STRAP POWER SUPPLIES	• CHANGE ACCEL OUTPUT FORMAT • ROTATE GYROS	
PERCENT MOD	10 –20%	10 –20%	<2%	<5%	< 5%	
DEV OR MOD COST ($1K) ON INSTRUMENT ONLY. FLIGHT TEST NOT INCLUDED	700	730	10	40	44	TBD
SUPPORT EQUIPMENT	NONE	NONE	OPTICAL ALIGNMENT (CLOSED LOOP)			
IMPACT ON VEHICLE	MINIMUM	MINIMUM	MINIMUM	COMPLEX MOUNTING SURFACE	THREE MUTUAL PERPENDICULAR MOUNTING SURFACES	

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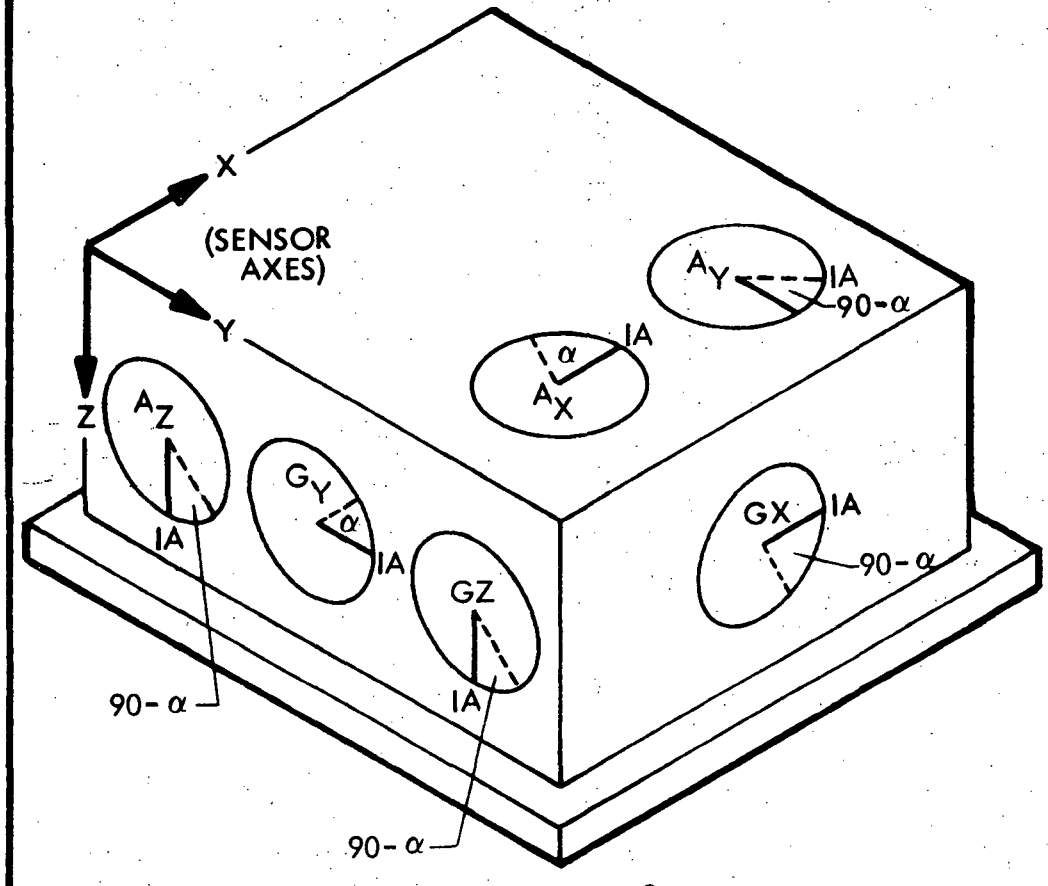
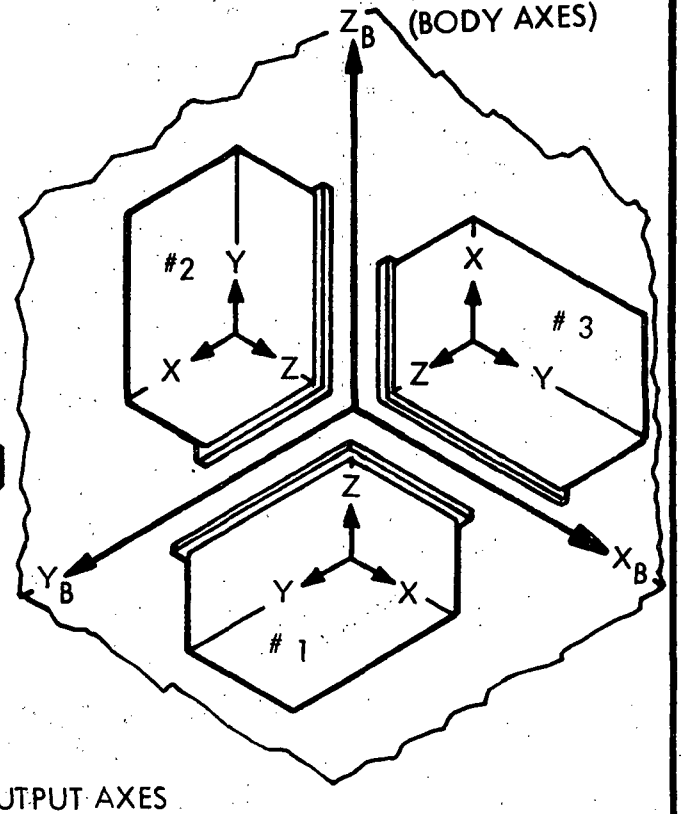
ROTATION OF SENSORS IN TRIAD STRAPDOWN IMU



THREE IMU'S MOUNTED ON THREE ORTHOGONAL SURFACES



INPUT AXES ROTATED 31° 43' 2.8" (α) ABOUT OUTPUT AXES
NEW IA DIRECTION SHOWN BY DOTTED LINES.

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THREE TRIAD STRAPDOWN ROTATED SENSORS

OUTPUT EQUATIONS

DODECAHEDRON AXES	GYRO	ACCELEROMETER
A	G_{X1} OR G_{Z2}	A_{Z2} OR A_{Y3}
B	G_{Y2}	A_{X3}
C	G_{X2} OR G_{Z3}	A_{Y1} OR A_{Z3}
D	G_{Y3}	A_{X1}
E	G_{X3} OR G_{Z1}	A_{Y2} OR A_{Z1}
F	G_{Y1}	A_{X2}

G_{X1}, ETC. = X AXIS GYRO FROM IMU NO. 1; A_{X1}, ETC. = X AXIS ACCELEROMETER FROM IMU NO. 1

BODY AXES

$$X_B = 1/2 \left[(A-B) \text{ SINE } \alpha + (C+D) \text{ COSINE } \alpha\right]$$
$$Y_B = 1/2 \left[(C-D) \text{ SINE } \alpha + (E+F) \text{ COSINE } \alpha\right]$$
$$Z_B = 1/2 \left[(E-F) \text{ SINE } \alpha + (A+B) \text{ COSINE } \alpha\right]$$

$\alpha = 31^\circ 43' 2.8''$

SOFTWARE SIMILAR TO MIT DODECAHEDRON

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IMU RECOMMENDATIONS AND RATIONALE

RECOMMENDED CONFIGURATION – 3 TRIAD STRAPDOWN WITH ROTATED SENSORS.

RECOMMENDED IMU – HONEYWELL INERTIAL SENSOR ASSEMBLY (ISA) DEVELOPED AND FLOWN ON AF AGENA

RATIONALE

- COST
  - LIMITED CHANGES TO ISA WILL MINIMIZE MODIFICATION COST
  - MODIFICATIONS TO PLATFORM EXTENSIVE (GIMBAL READOUT, Z-AXIS ACCELEROMETER LOOP, LOW FREQUENCY VIBRATION RESONANCE).
  - DODECAHEDRON REQUIRES FULL QUALIFICATION TO SPACE ENVIRONMENTS.
- RISK
  - ISA IS SPACE PROVEN AND QUALIFIED
  - A NUMBER OF ISA GYROS (G6334A) HAVE BEEN BUILT AND FLOWN ON ANOTHER SPACE PROGRAM
  - EXTENSIVE LMSC EXPERIENCE IN STRAPDOWN SYSTEMS (IMU AND ATTITUDE SENSORS) WILL BE EXCELLENT STARTING BASE FOR SHUTTLE.

ORBITER ATTITUDE CONTROL FOR PAYLOAD SUPPORT (1σ VALUES)

ITEM	STATUS	REMAINING TASKS
ATTITUDE REF UNCERTAINTY (0.01 TO 0.1 DEG) (36 TO 360 SEC)	CAPABILITY LIMITED BY (~360 SEC / 0.1°) C-IV RESOLVERS AND ATM OPTICAL SENSOR (30 SEC)	DUAL SPEED RESOLVERS (~20 SEC) STRAPPED DOWN IMU (~15 SEC) PRECISION OPTICAL SENSOR (~20 SEC)
ATTITUDE REF DRIFT RATE	CAROUSEL IV DRIFT: Z-AXIS ~180 SEC/HR Y- AND X-AXES ~10 SEC	REORIENT PLATFORMS X, Y, AND Z AXES ~10 SEC
NAVIGATION UNCERTAINTY	Δα~74 SEC (SUBPOINT) FOR OPEN-LOOP POINTING AT EARTH & 0.1 NM POSITION UNCERTAINTY	PRECISE AUTONOMOUS NAVIGATION TO INCREASE NAVIGATION UPDATE FREQUENCY AND AUGMENT MSFN DATA.
LIMIT CYCLE ATTITUDE CONTROL MODE { ±0.01 TO ±0.1 DEG; ±0.01 TO ±0.03 DEG/SEC } RQMTS	BASELINE LIMIT CYCLE CHAR: LIMIT CYCLE RATES θ = ±0.005 DEG/SEC ψ = ±0.002 DEG/SEC φ = ±0.02 DEG/SEC } 16M-SEC PULSE WIDTH PROPELLANT CONSUMPT. RATES 7 LB/HR FOR ±0.5 DEG (ALL AXES) 35 LB/HR FOR ±0.1 DEG 350 LB/HR FOR ±0.01 DEG	1. REDUCE ROLL RATE CANCEL THRUST REDUCE ROLL MOMENT CMG CONTROL 2. DETERMINE EFFECTS OF DISTURBANCES 3. SIZE CMG FOR ROLL AXIS
RELIABILITY (30 DAY LIFE RQMT)	REDUNDANT CONFIG PRESENTLY BASED ON 7 DAY ORBITAL LIFE	30-DAY RELIABILITY ANALYSIS

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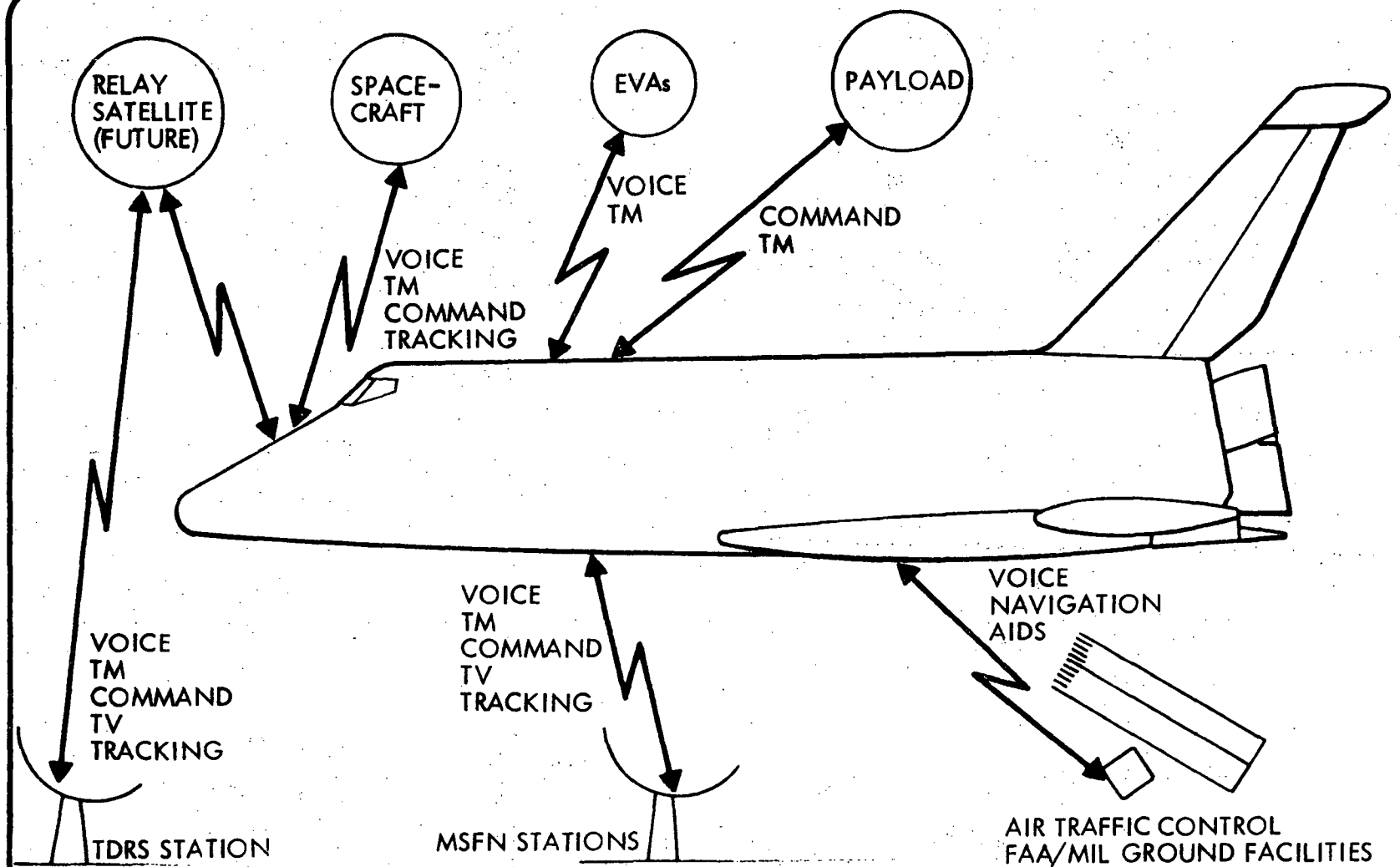
BASELINE REQUIREMENTS SUMMARY

COMMUNICATIONS AND TRACKING

- AIRCRAFT OPERATIONS
  - TACAN FOR RANGE AND HEADING
  - UHF VOICE TRANSCEIVER
- SPACECRAFT OPERATIONS
  - S-BAND TRANSCEIVER
    - VOICE
    - UPLINK – COMMAND AND NAVIGATION UPDATES
    - DOWNLINK – TELEMETRY
    - TELEVISION
  - UHF RANGING/VOICE – RENDEZVOUS RANGING

RADIO LINKS

VOICE – TM – COMMAND – TRACKING – TV



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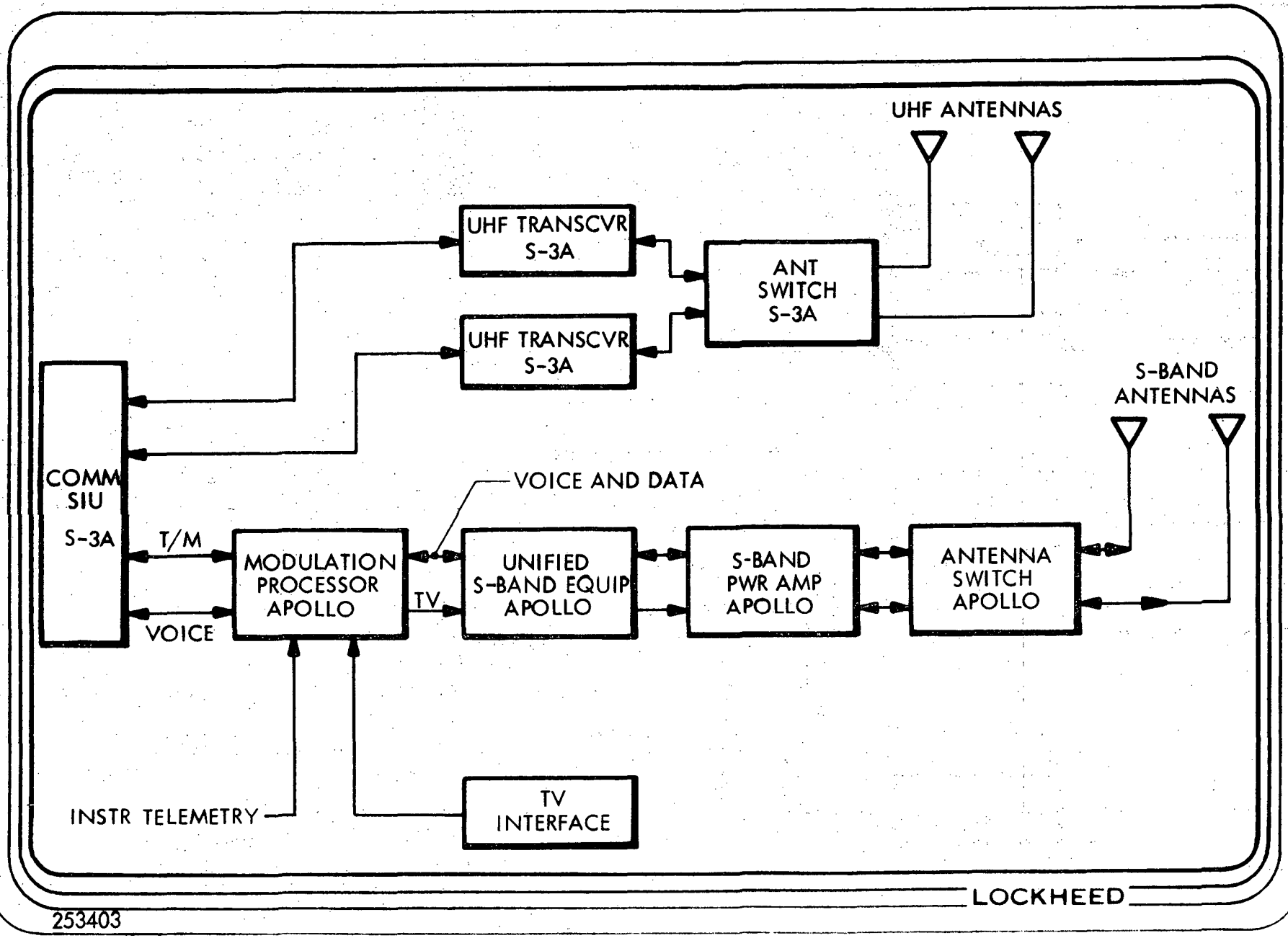
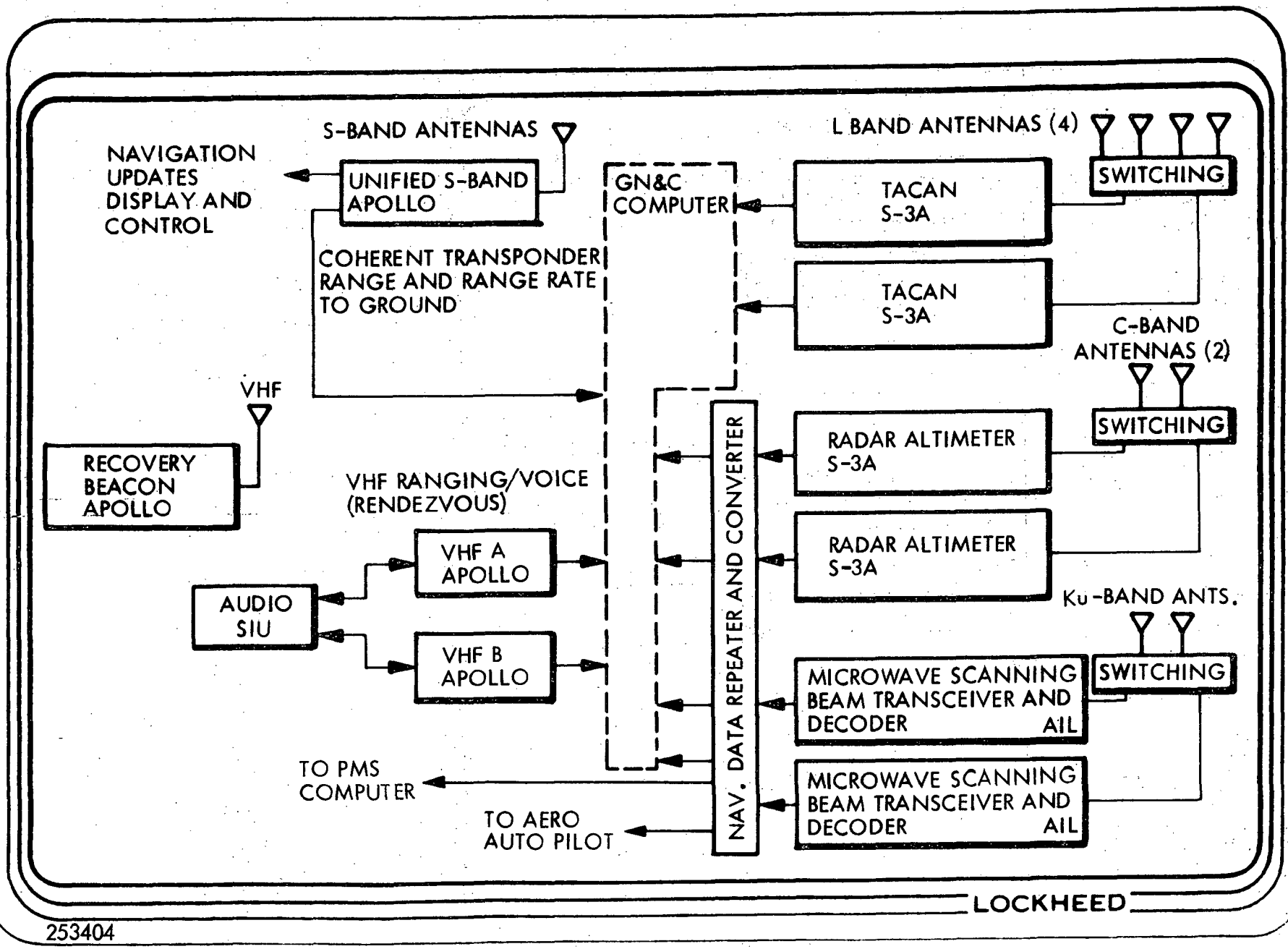
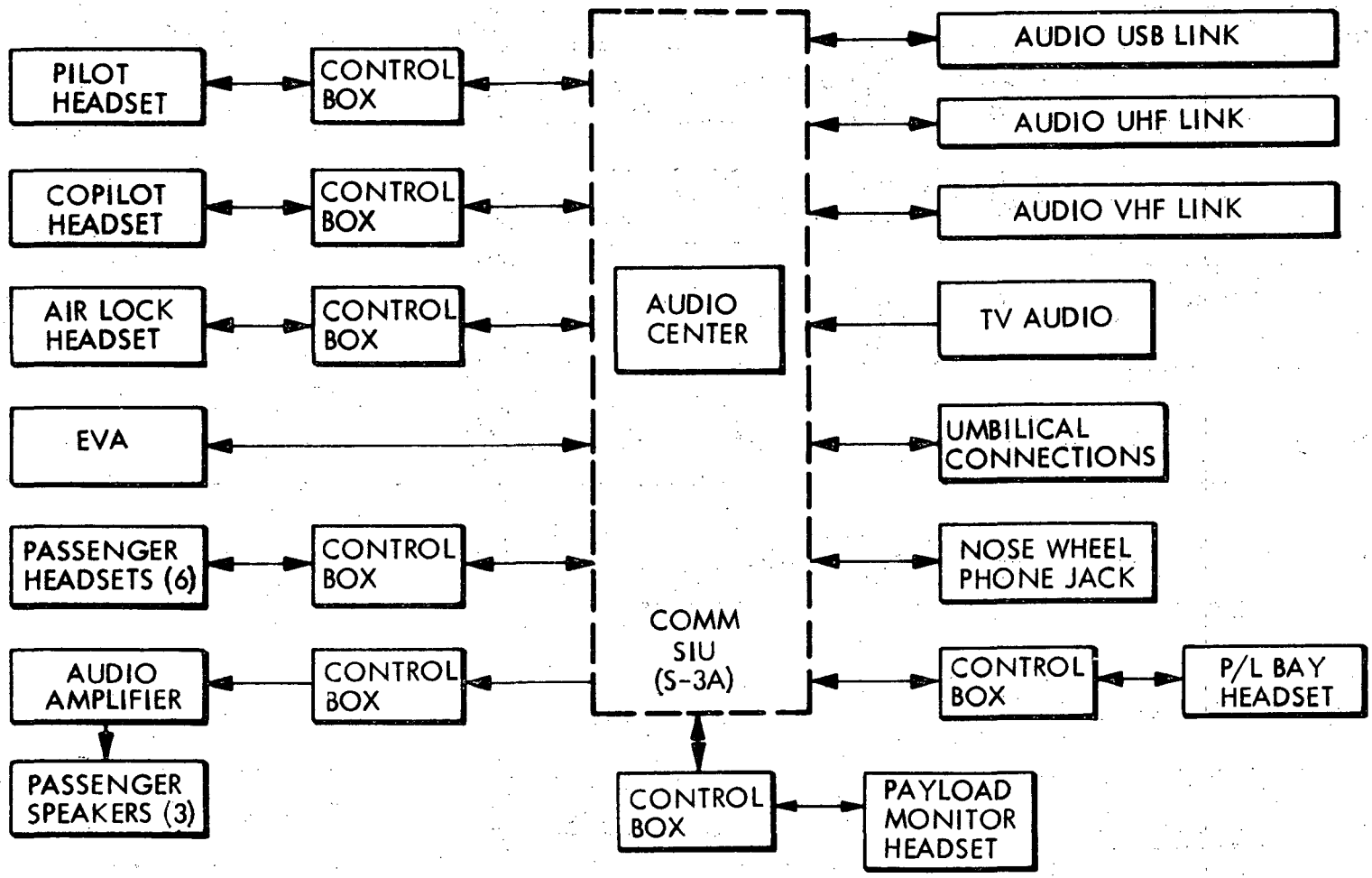
COMMUNICATIONS/RF



COMMUNICATIONS/TRACKING



COMMUNICATIONS/VOICE



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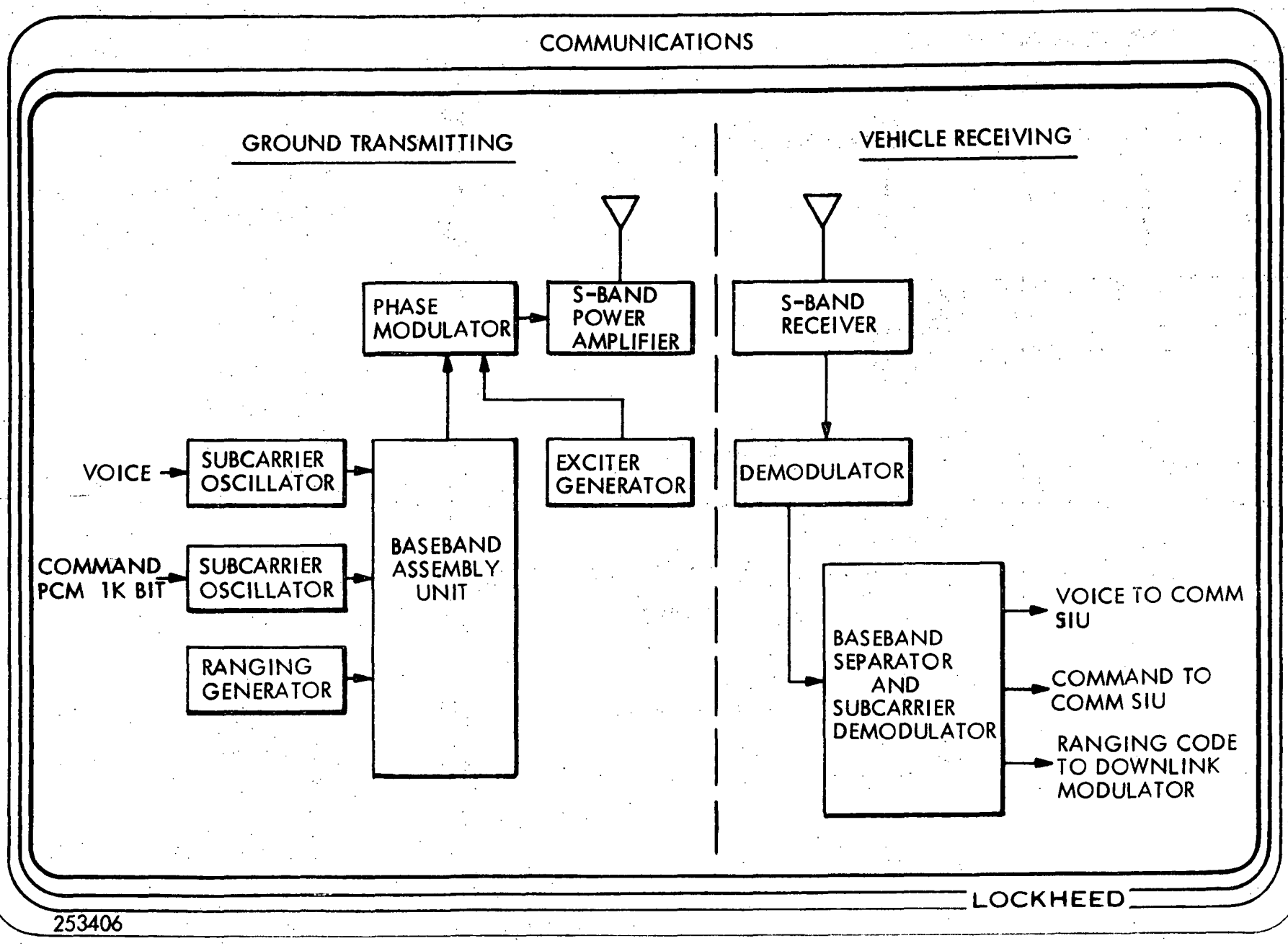
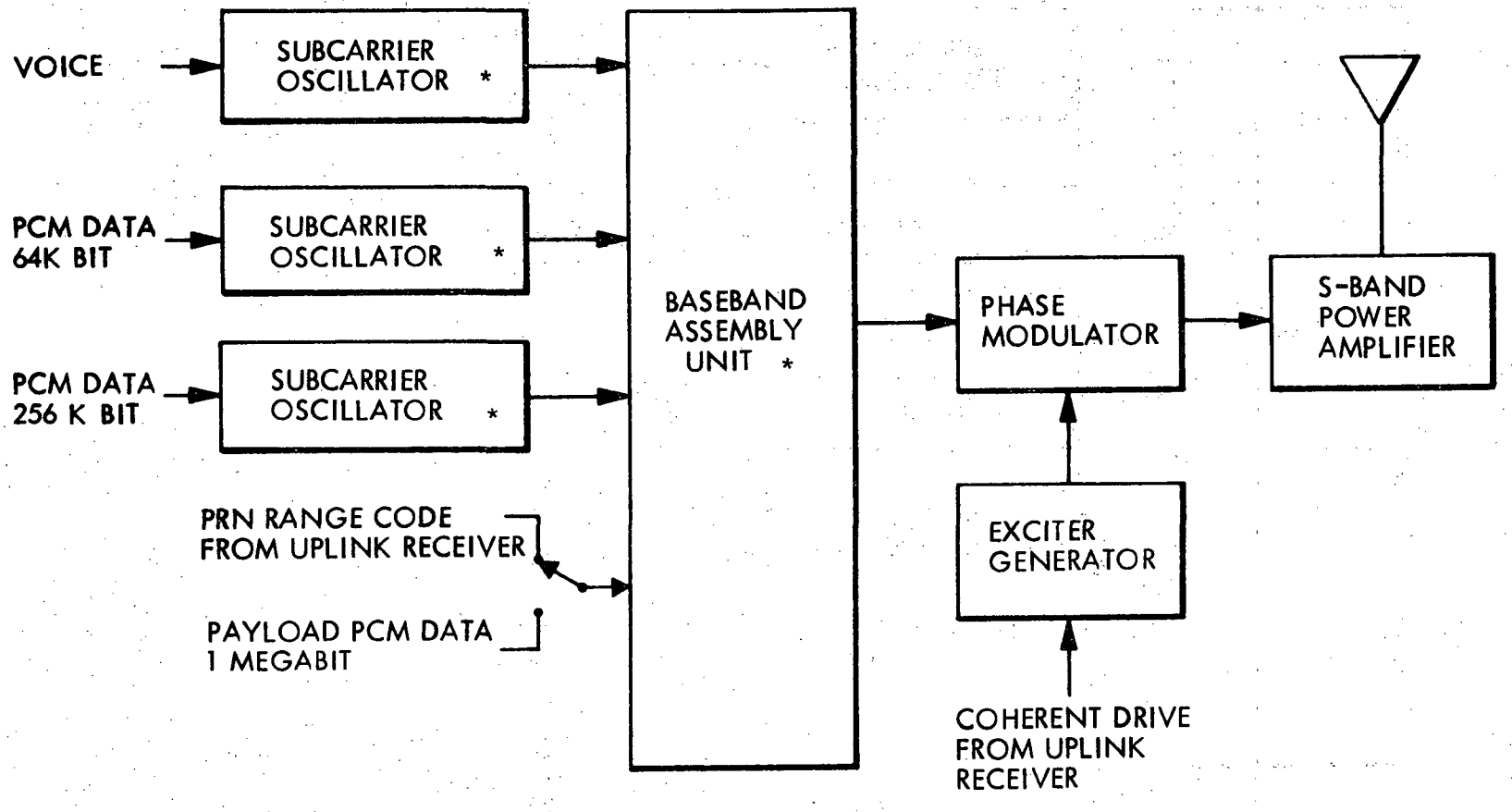
253405

S-BAND UPLINK



S-BAND DOWNLINK

COMMUNICATIONS

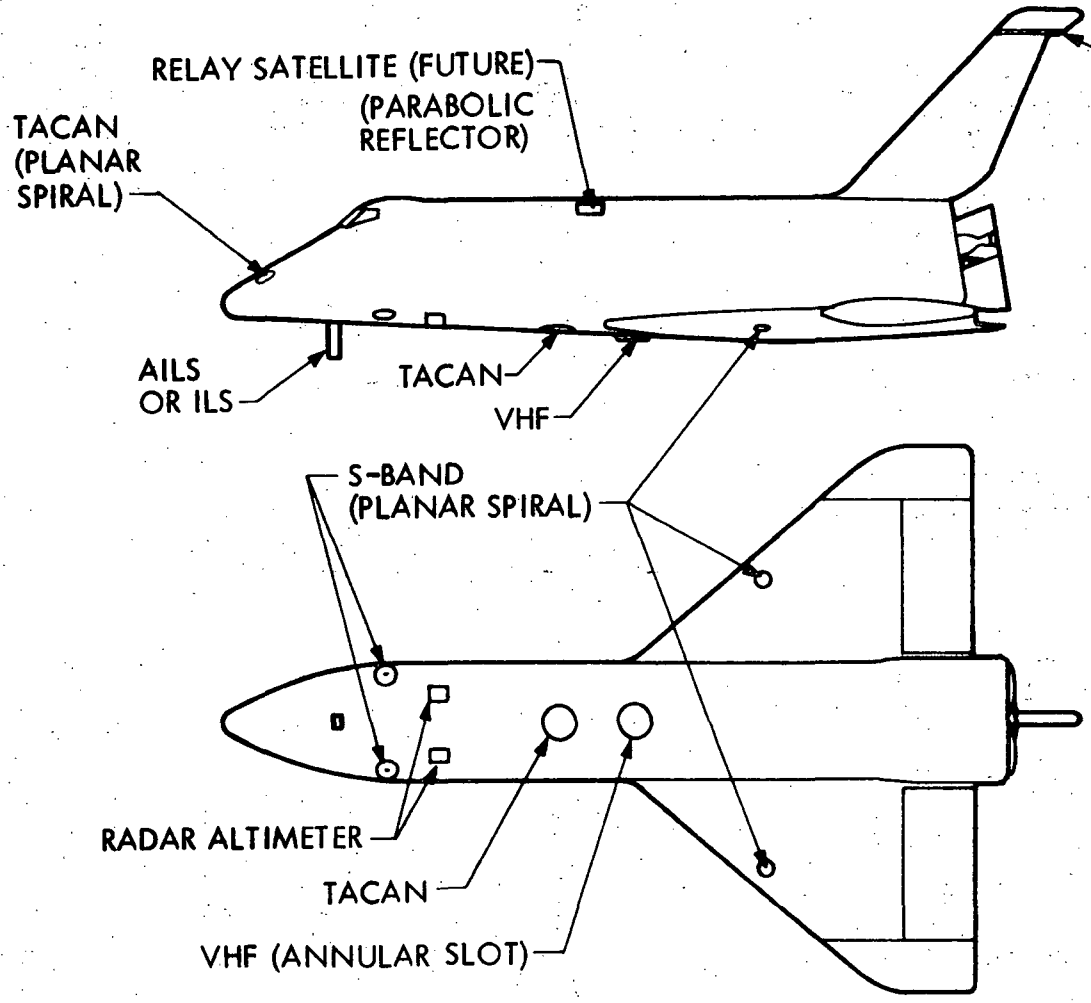


* PART OF PREMODULATION PROCESSOR

LOCKHEED

253407

COMMUNICATIONS ANTENNA LOCATIONS



VHF 225-400 MHz
- VHF RANGING/VOICE (RENDEZVOUS)
- VHF RECOVERY BEACON
- EVA
- ATC VOICE TRANSEIVER

TACAN 960 - 1215 MHz

S-BAND 2025 - 2300 MHz

ILS 108 - 110 MHz
330 - 335 MHz
EARLY HORIZONTAL FLIGHT

RADAR ALTIMETER 4300 MHz

AILS SCANNING BEAM
RADAR 15.4 to 15.7 GHz
OPERATIONAL FLIGHT

LOCKHEED

253408

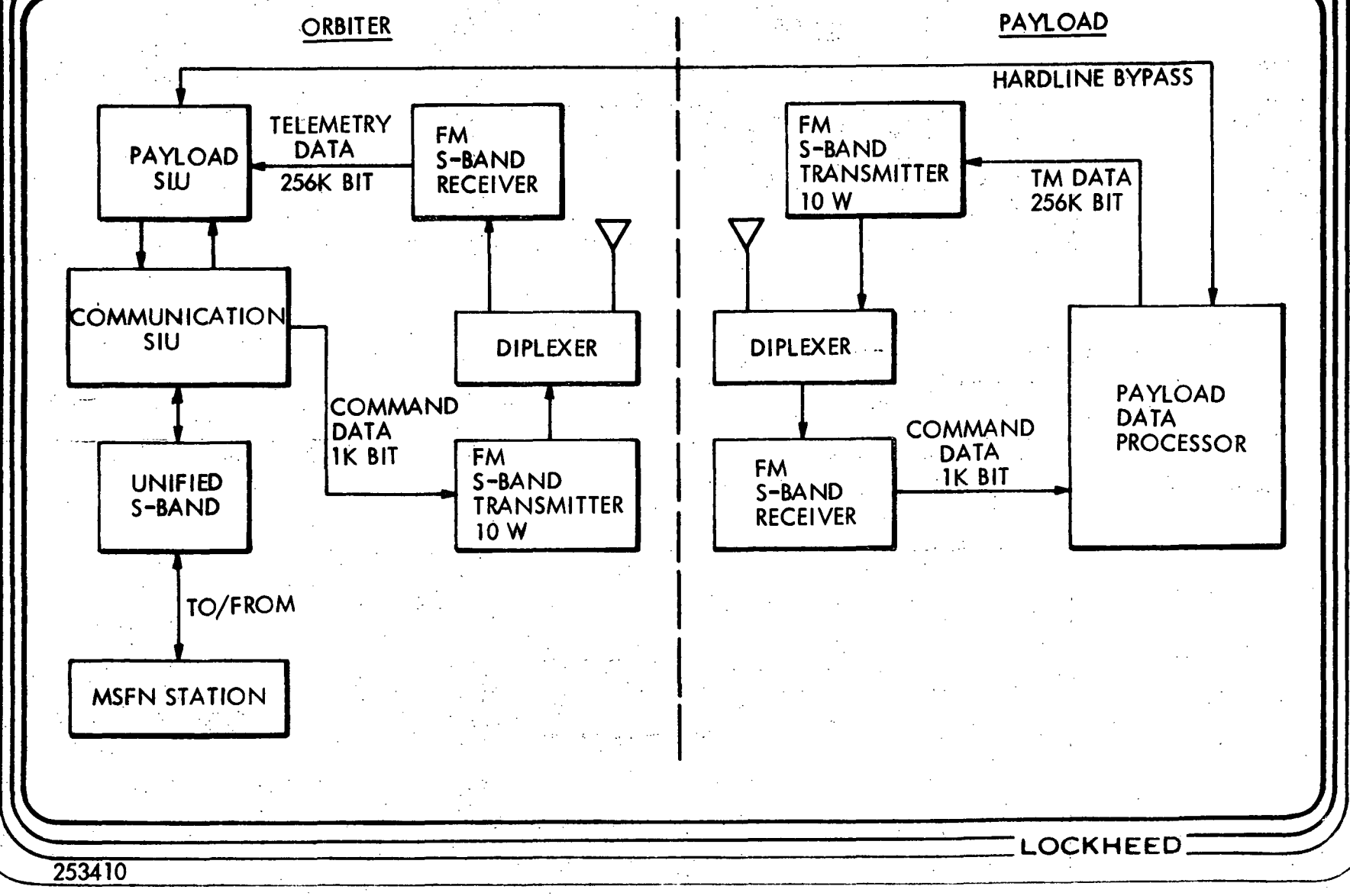
COMMUNICATIONS SUBSYSTEM REDUNDANCY

ITEM	REQUIRED SAFE RETURN	REQUIRED MISSION SUCCESS	SELECTED	RATIONALE
TACAN	1	0	2	2 ACTIVE S-BAND BACKUP
UHF VOICE TRANSCEIVER	1	0	2	1 ACTIVE 1 STANDBY FAULT ISOLATION AUTOMATIC SWITCHOVER
S-BAND TRANSCEIVER	0	1	2	ELEMENTS ARE REDUNDANT AND SWITCHABLE SEPARATELY. FAULT ISOLATION/PANEL INDICATORS
VHF RANGING AND VOICE	0	1	2	1 ACTIVE, 1 STANDBY S-BAND BACKUP
ILS (HORIZONTAL FLIGHT) AILS	1	0	2	2 ACTIVE
RADAR ALTIMETER	1	0	2	2 ACTIVE
VHF RECOVERY BEACON	0	0	1	REQUIRED FOR D.F. IF "DOWN AT SEA"

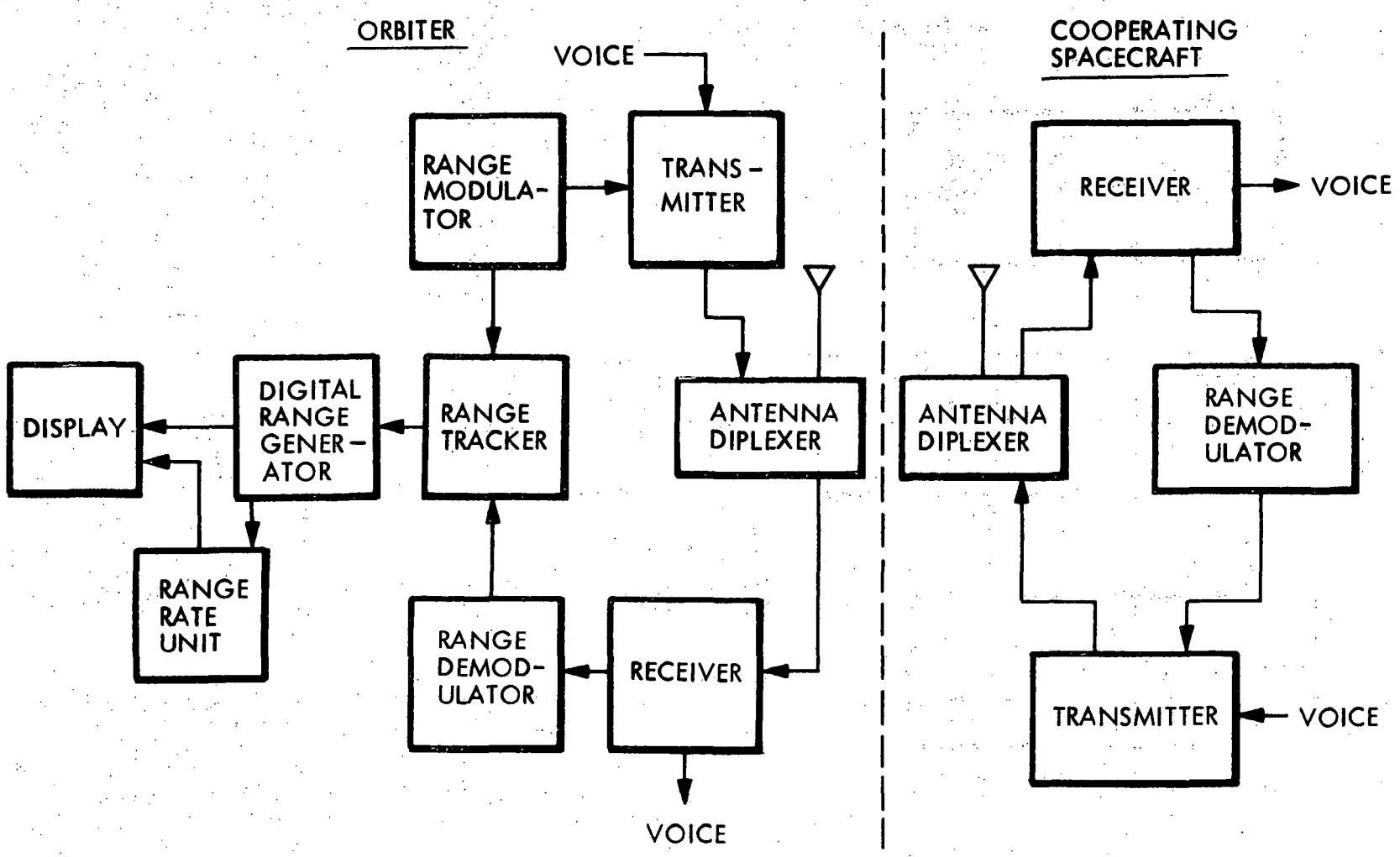
LOCKHEED

253409

PAYLOAD/ORBITER COMMUNICATIONS INTERFACE

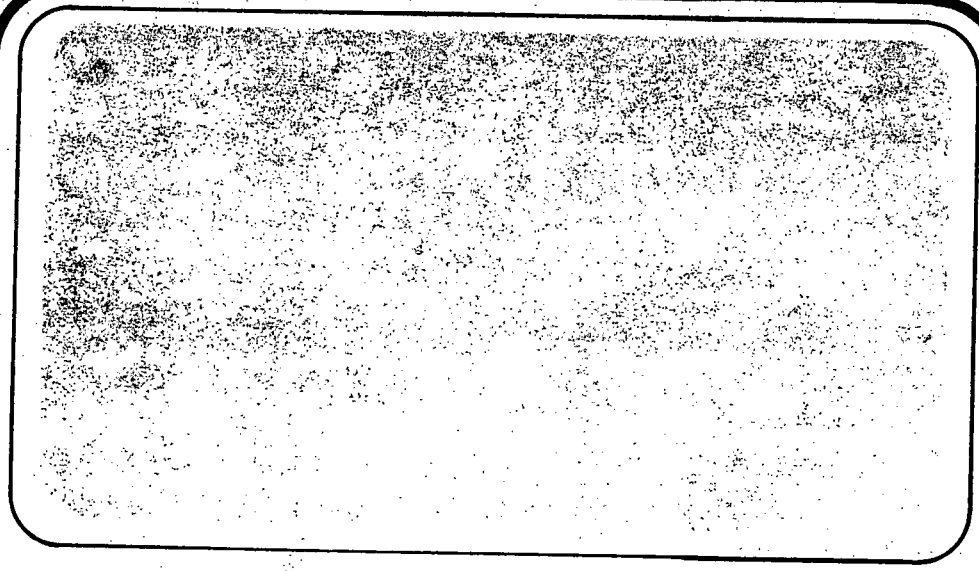


VHF COMMUNICATIONS RENDEZVOUS RANGE RATE



LOCKHEED

253411



Performance Monitoring and Instrumentation

ACS Avionics Review

PMS REQUIREMENTS SUMMARY

TD 3009 - UNIVAC 1832

	MINIMUM REQUIRED	MAXIMUM CAPABILITY	REQUIRED MARGIN (PERCENT)	ACTUAL MARGIN (PERCENT)
DUAL CPU SPEED (K OPS/SEC)	294	722	100	146
CORE MEMORY CAPACITY (K WORDS)	37	98	50	165
I/O CHANNELS	12	78	100	550
I/O RATE (K WORDS/SEC)	158	1300	100	823

LOCKHEED

253501

PMS UTILIZATION: CPU SPEED, K-OPS/SEC

	HFT	VFT	INITIAL OP'L	FINAL OP'L
ONBOARD CHECKOUT	150	256	256	256
TELEMETRY FORMAT AND DISPLAY	11	11	11	11
EXECUTIVE AND ABORT WARNING	35	109	117	119
GN&C BACKUP		215	215	215
ONBOARD COFIRM		50	50	50
SYSTEM MANAGEMENT AIDS		1	1	1
AVIONICS CONFIGURATION CONTROL			10	10
CONSUMABLES MANAGEMENT			30	30
RENDEZVOUS COMPUTATION			INCL IN GN&C	
PAYLOAD MANAGEMENT				120 REPLACES GN&C
A/C AND S/C FLIGHT CONTROLS				INCL IN GN&C
NON-AVIONICS CONFIGURATION CONTROL				20
MISSION PLANNING				10
TOTAL	196	642	690	722

DUAL CPU CAPACITY AVAILABLE: 722

LOCKHEED

253502

PMS UTILIZATION: CORE MEMORY ALLOCATION, K-WORDS

	HFT	VFT	INITIAL OP'L	FINAL OP'L
ONBOARD CHECKOUT	12	19	19	19
TELEMETRY FORMAT AND DISPLAY	11	11	11	11
EXECUTIVE AND ABORT WARNING	2	4	6	8
GN&C BACKUP		11	11	11
ONBOARD COFIRM		6	6	8
SYSTEM MANAGEMENT AIDS		2	4	4
AVIONICS CONFIGURATION CONTROL			4	4
CONSUMABLES MANAGEMENT			4	4
RENDEZVOUS COMPUTATION			INCL IN GN&C	
PAYLOAD MANAGEMENT				10
A/C AND S/C FLIGHT CONTROLS				INCL IN GN&C
NON-AVIONICS CONFIGURATION CONTROL				8
MISSION PLANNING				10 REPLACES GN&C
TOTAL	25	53	65	87*
CORE MEMORY CAPACITY	32/65	65	65	98*

*ASSUMES THREE MEMORY BANKS

LOCKHEED

253503

PMS UTILIZATION: I/O RATE, K-WORDS/SEC

	HFT	VFT	INITIAL OP'L	FINAL OP'L
ONBOARD CHECKOUT	10	19	19	19
TELEMETRY FORMAT AND DISPLAY	9	9	9	9
EXECUTIVE AND ABORT WARNING	0.1	0.1	0.1	0.1
GN&C BACKUP*		1.5	1.5	1.5
ONBOARD COFIRM		0.5	0.5	0.5
SYSTEM MANAGEMENT AIDS		0.1	0.1	0.1
AVIONICS CONFIGURATION CONTROL			0.2	0.2
CONSUMABLES MANAGEMENT			0.1	0.1
RENDEZVOUS COMPUTATION			0.1	0.1
PAYLOAD MANAGEMENT**				10
A/C AND S/C FLIGHT CONTROLS				1
NON-AVIONICS CONFIGURATION CONTROL				0.5
MISSION PLANNING				0.3
TAPE AND DRUM	48	106	130	178
TOTAL	67.1	136.2	160.6	220.4

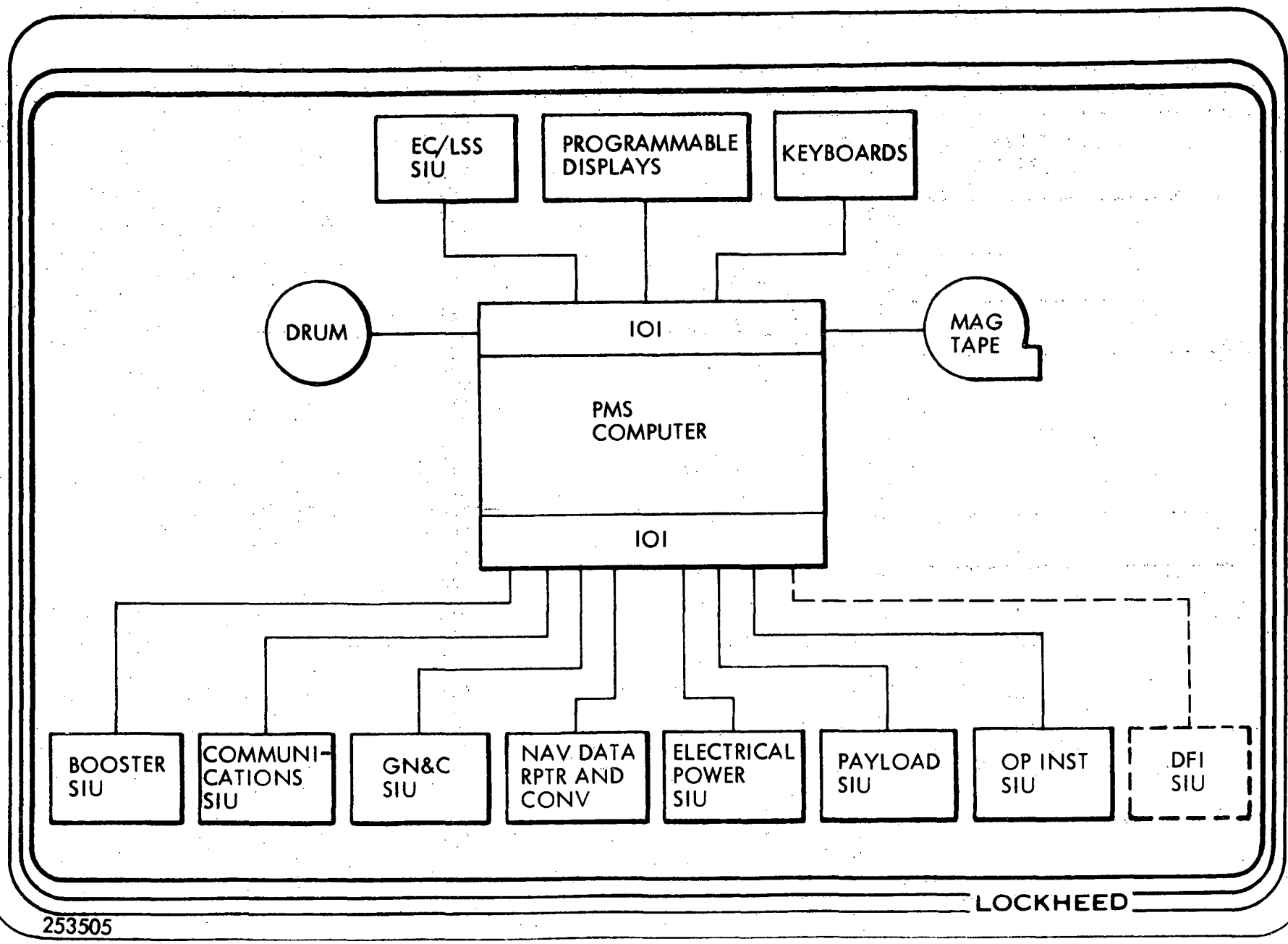
I/O CAPACITY AVAILABLE: 1,300

*ASSUMES ACTIVE
**AVERAGE RATE ACTIVE

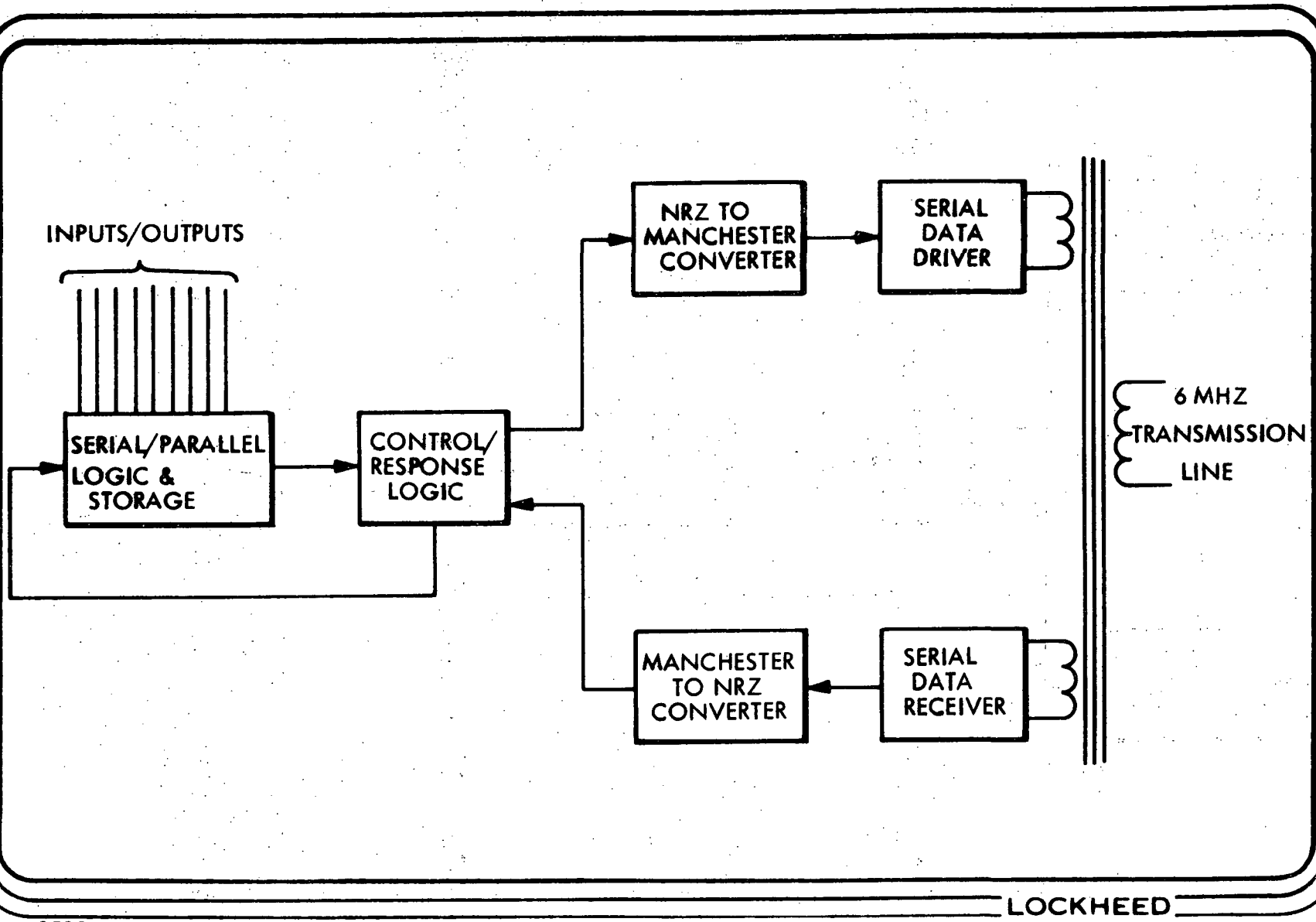
LOCKHEED

253504

PERFORMANCE MONITORING SUBSYSTEM



PMS INPUTS/OUTPUTS INTERFACE



SUBSYSTEM INTERFACE UNIT FUNCTIONS

BITE STATUS STORAGE (ALL SUBSYSTEMS)

DIGITAL COMMUNICATION INTERFACE (ALL EXCEPT EPS AND EC/LSS)

CONFIGURATION CONTROL (ELECTRICAL POWER, COMMUNICATIONS)

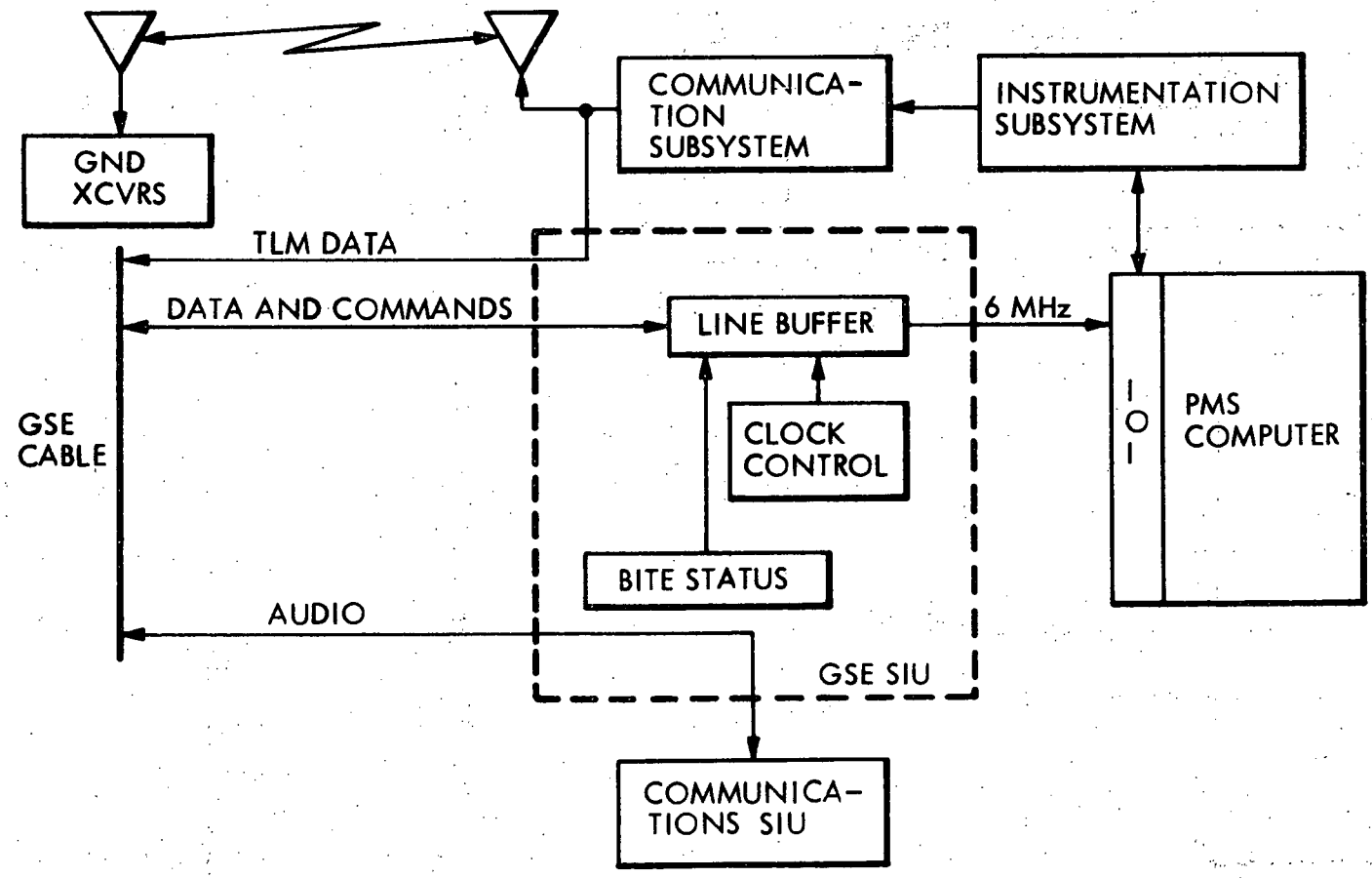
SUBSYSTEM CONTROL (INSTRUMENTATION, EC/LSS)

CABLING JUNCTION (ALL SUBSYSTEMS)

LOCKHEED

253507

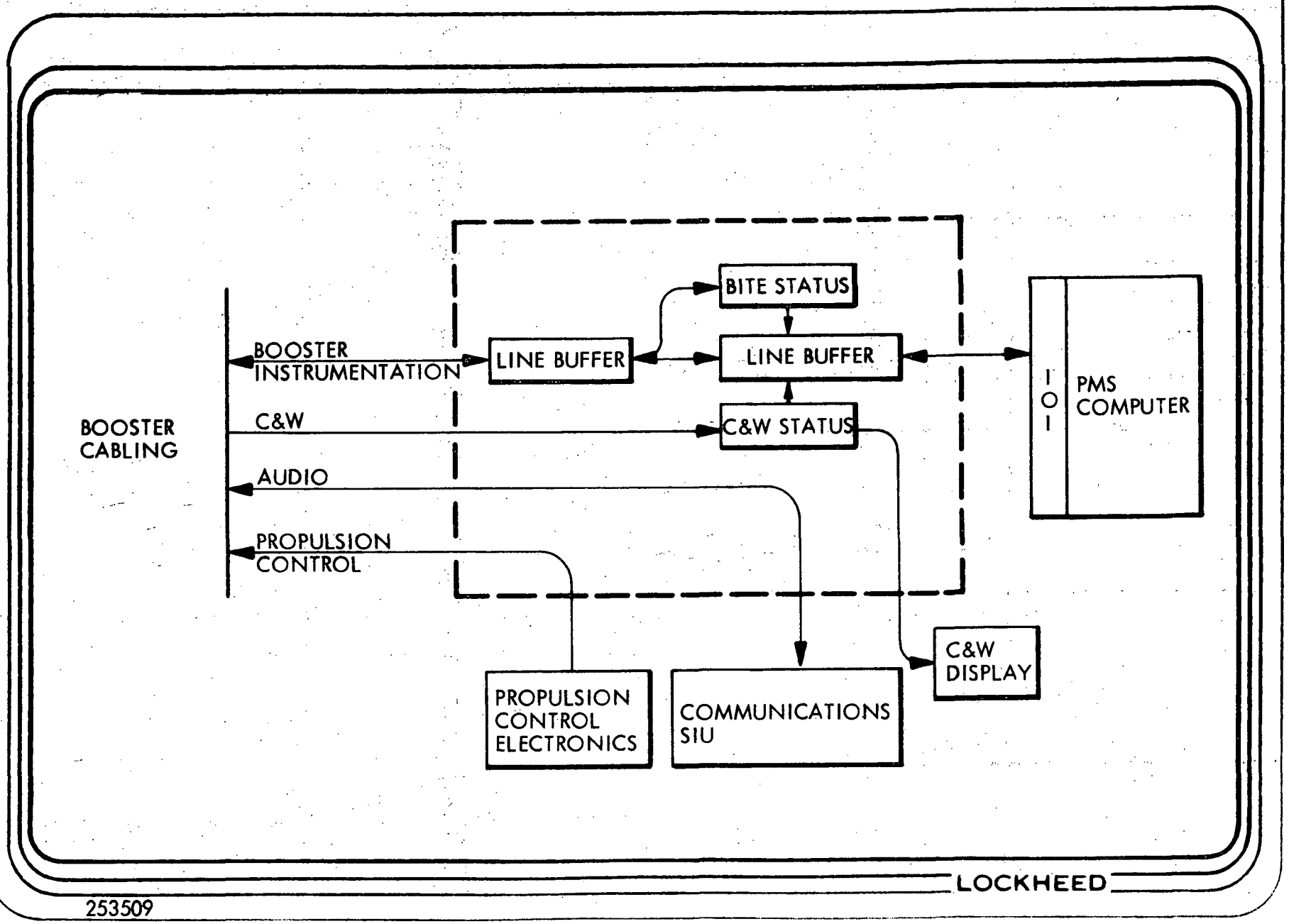
PMS/GSE INTERFACE



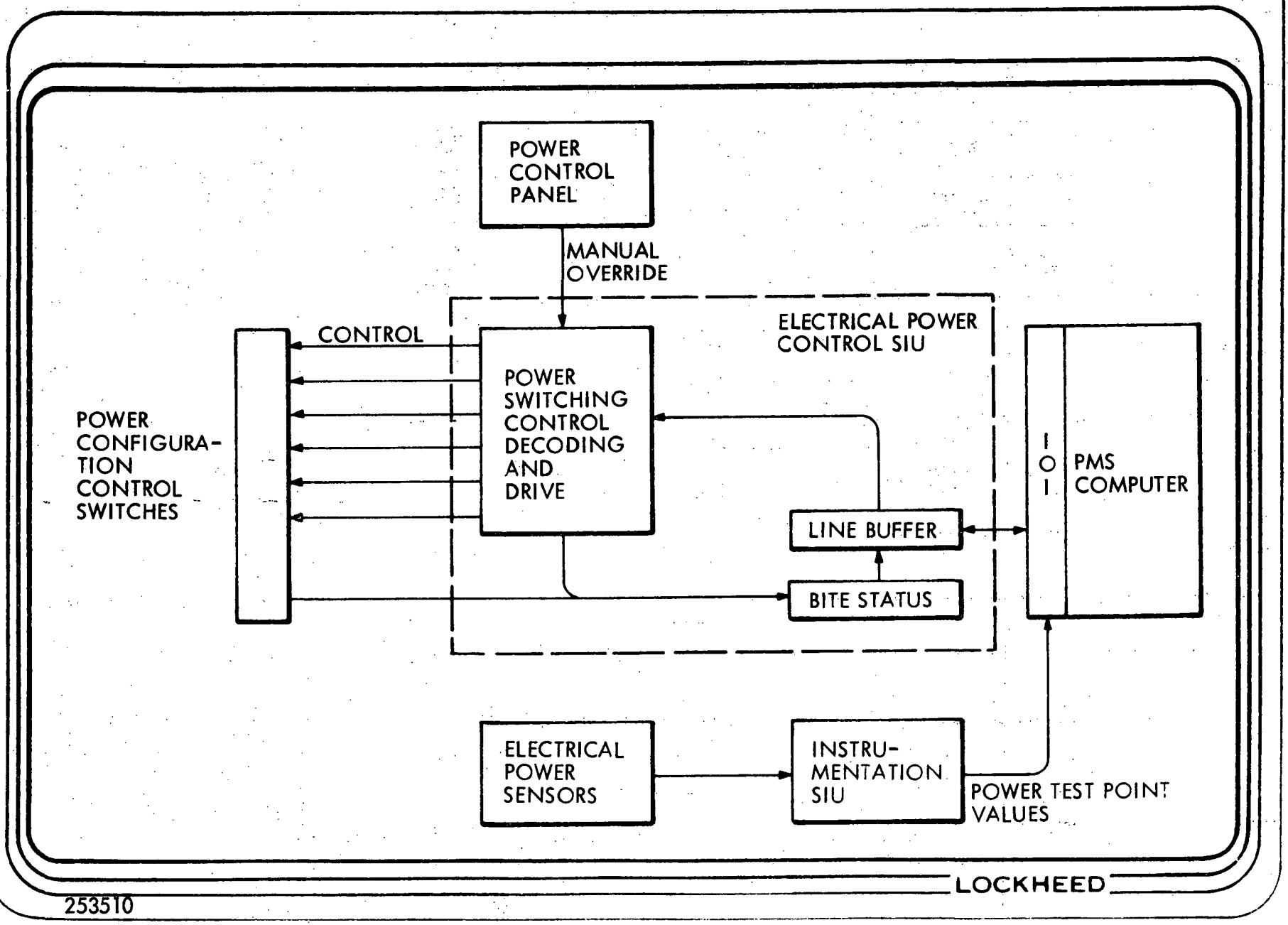
LOCKHEED

253508

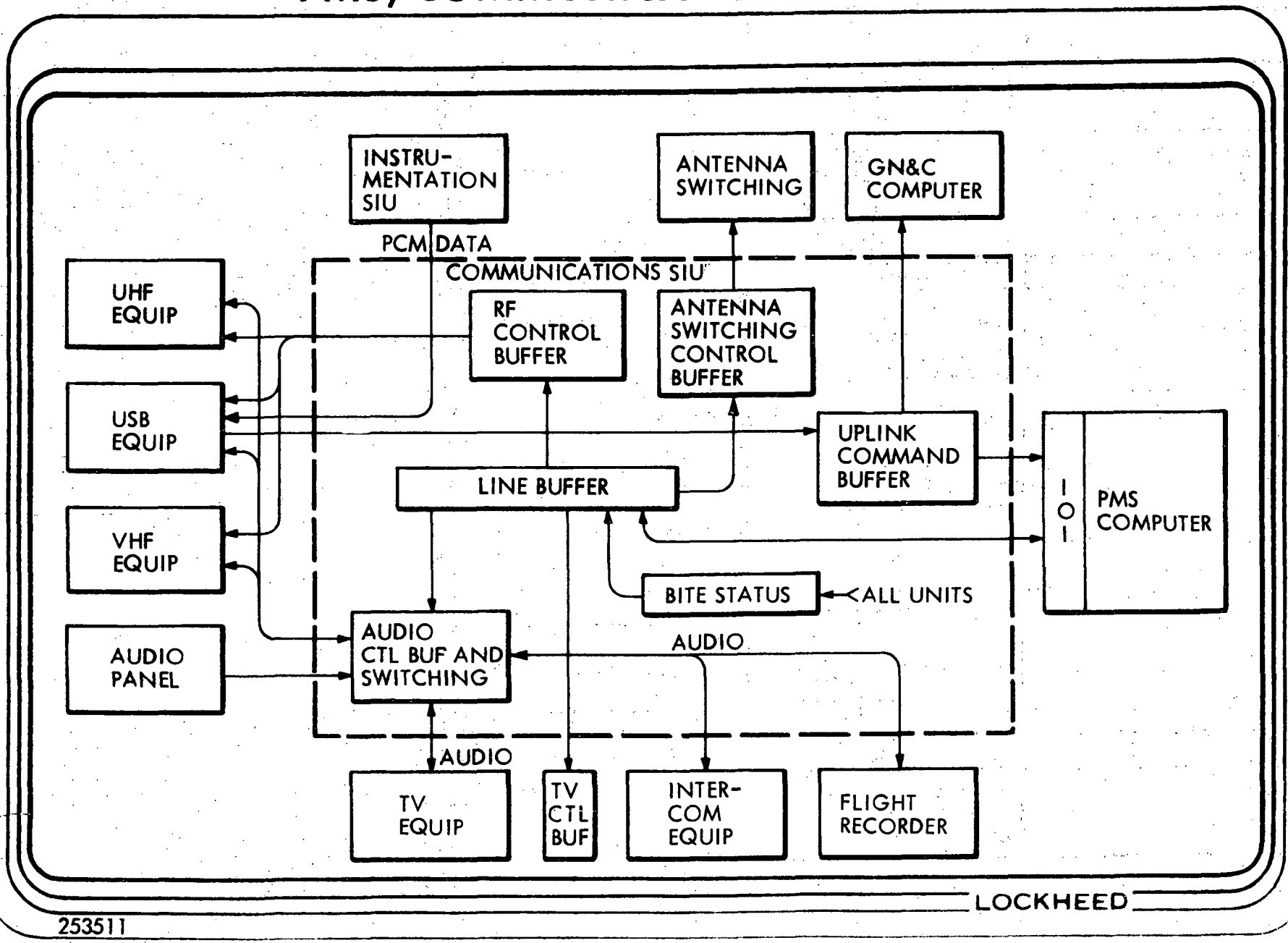
PMS/BOOSTER INTERFACE



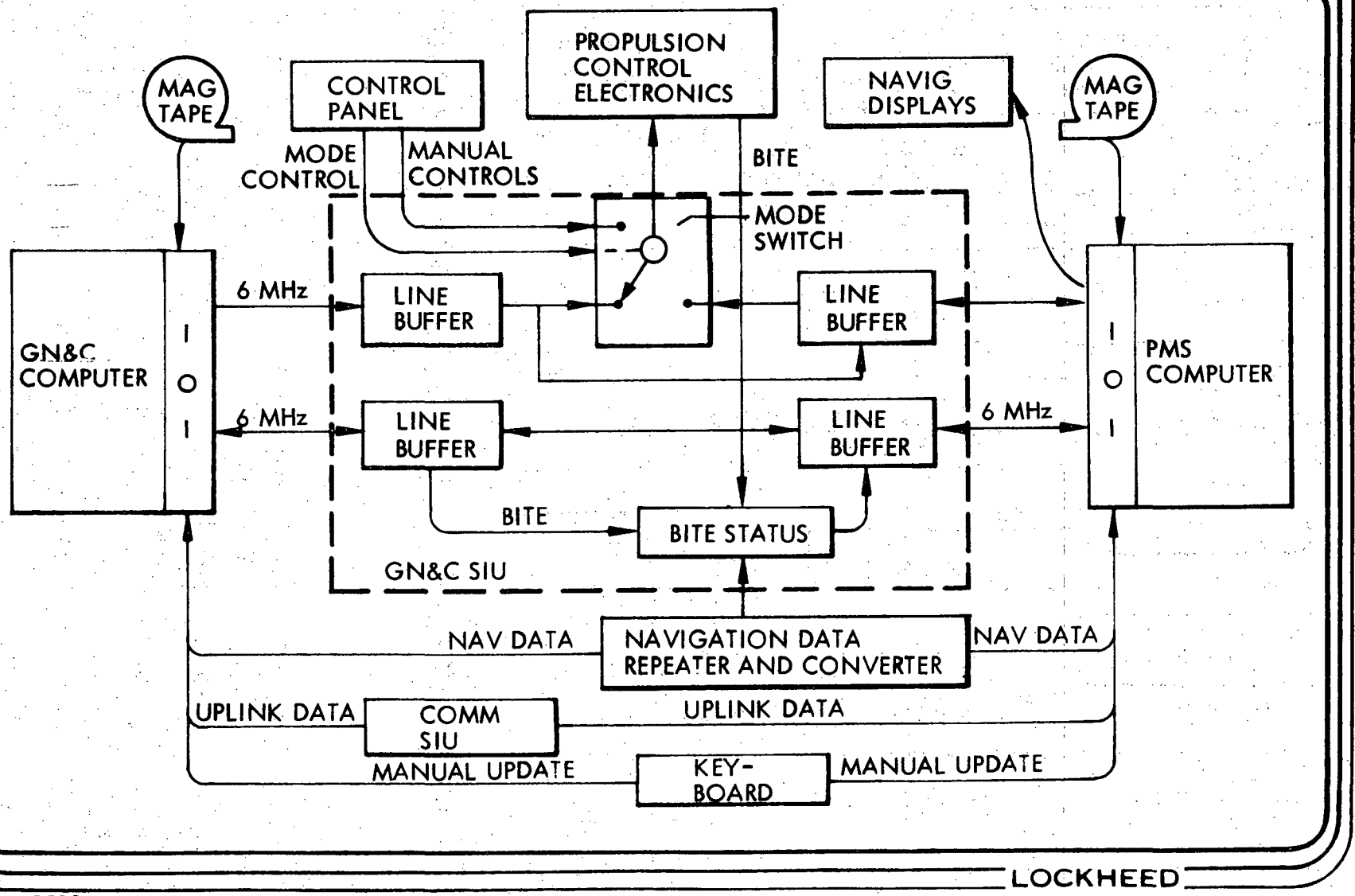
PMS/ELECTRICAL POWER CONTROL INTERFACE



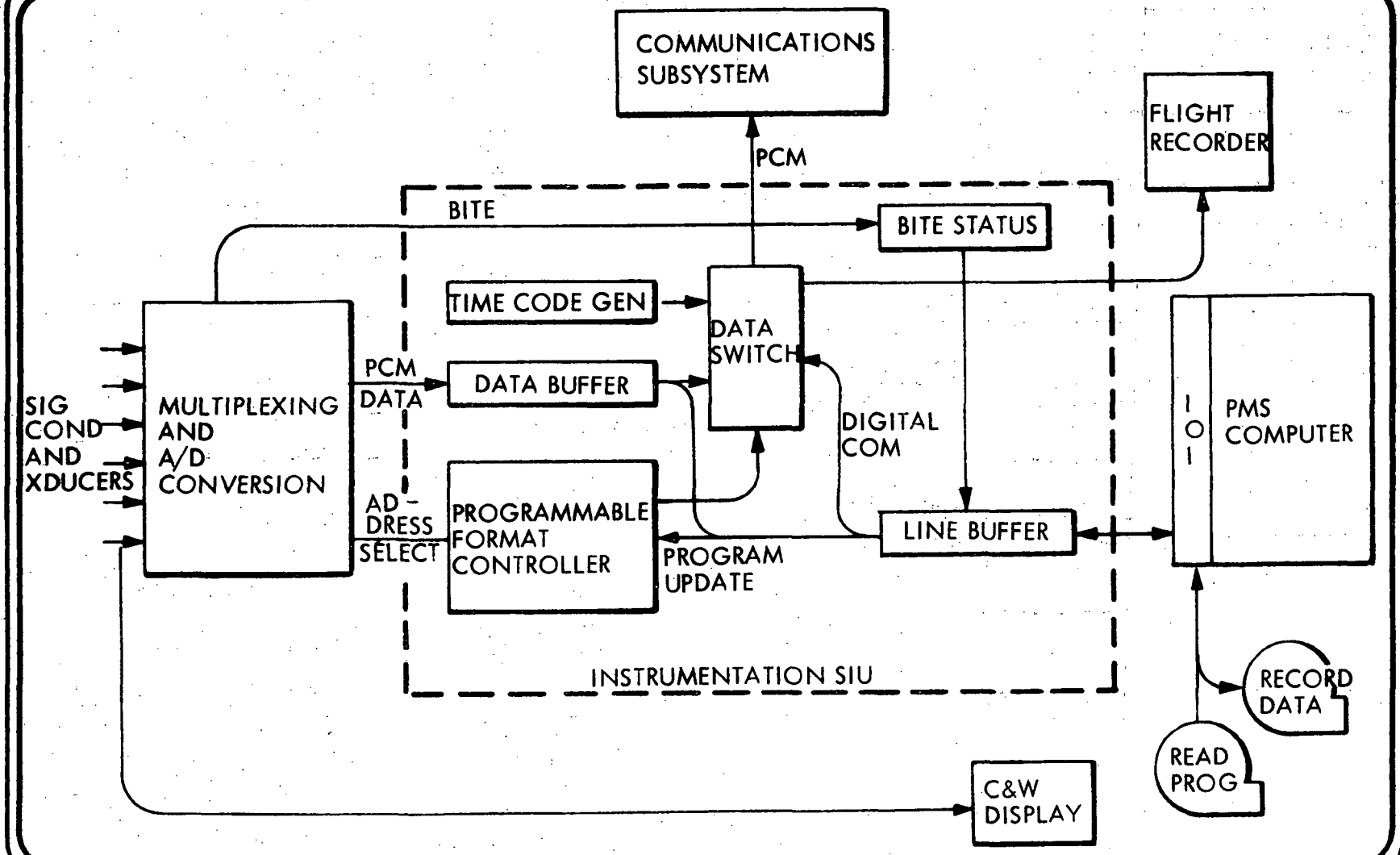
PMS/COMMUNICATIONS INTERFACE



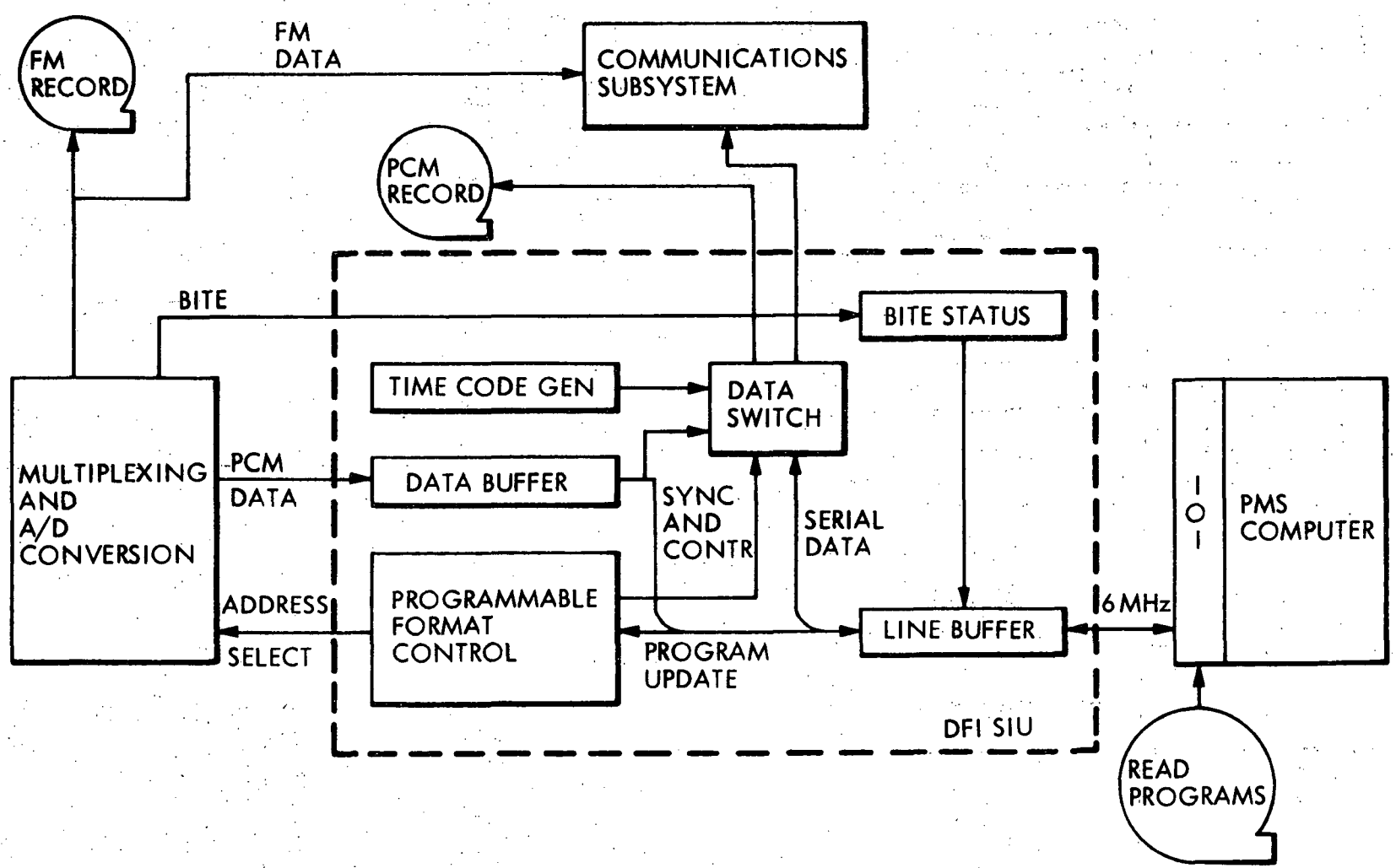
PMS/GN &C INTERFACE



PMS/INSTRUMENTATION INTERFACE



PMS/DFI INTERFACE



INSTRUMENTATION REQUIREMENTS SUMMARY

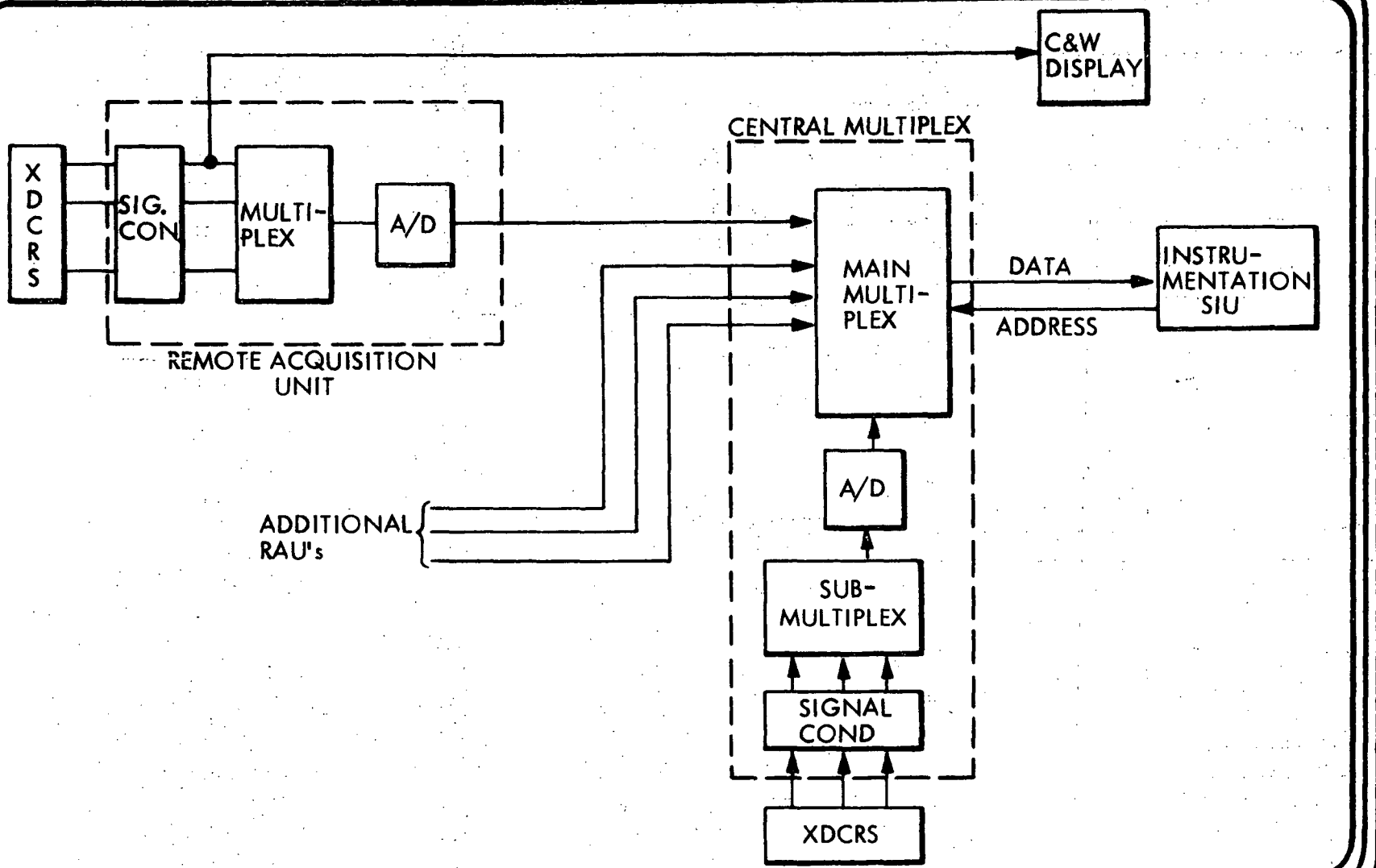
TD 3009 - LMSC BASELINE

	REQUIREMENT	BASELINE
DFI	DEDICATED OVERLAY	COMPLIES
RECORDERS	PCM	COMPLIES
	FM	COMPLIES
	VOICE	COMPLIES
	LOOP	1/2 HR FLIGHT RECORDER
	DUMP	PCM, FM
PCM FORMAT	PROGRAMMABLE	COMPLIES

LOCKHEED

253515

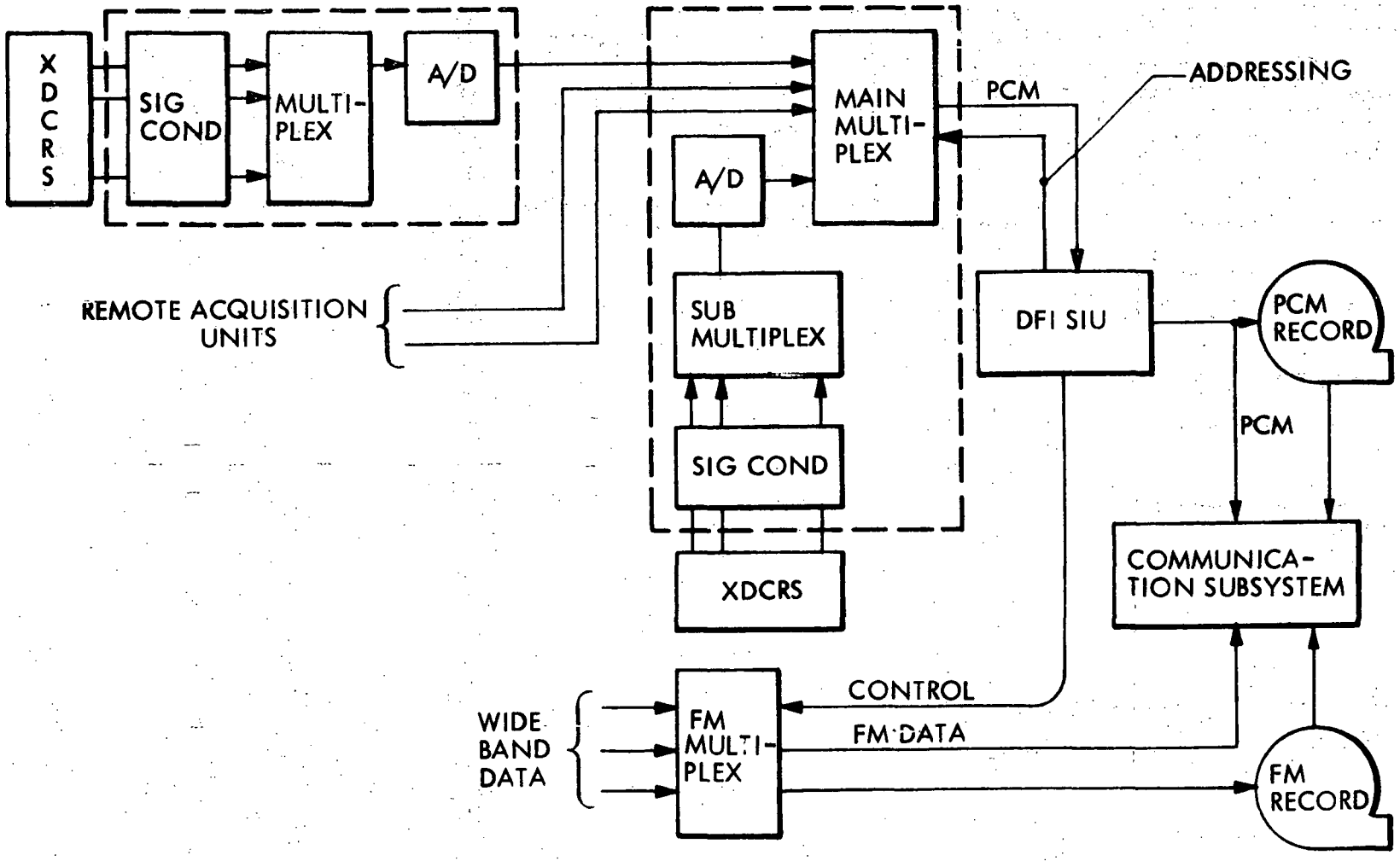
INSTRUMENTATION SUBSYSTEM



LOCKHEED

253516

DFI SUBSYSTEM



INSTRUMENTATION REDUNDANCY RATIONALE

FLIGHT CRITICAL CHANNELS	HARDWIRED; MULTIPATH MULTIPLEX BACKUP
PERFORMANCE MONITORING	REDUNDANCY FURNISHED BY MONITORING RELATED SIGNALS
RECORDING	REDUNDANCY FURNISHED BY LOOP RECORDER AND TELEMETRY LINK

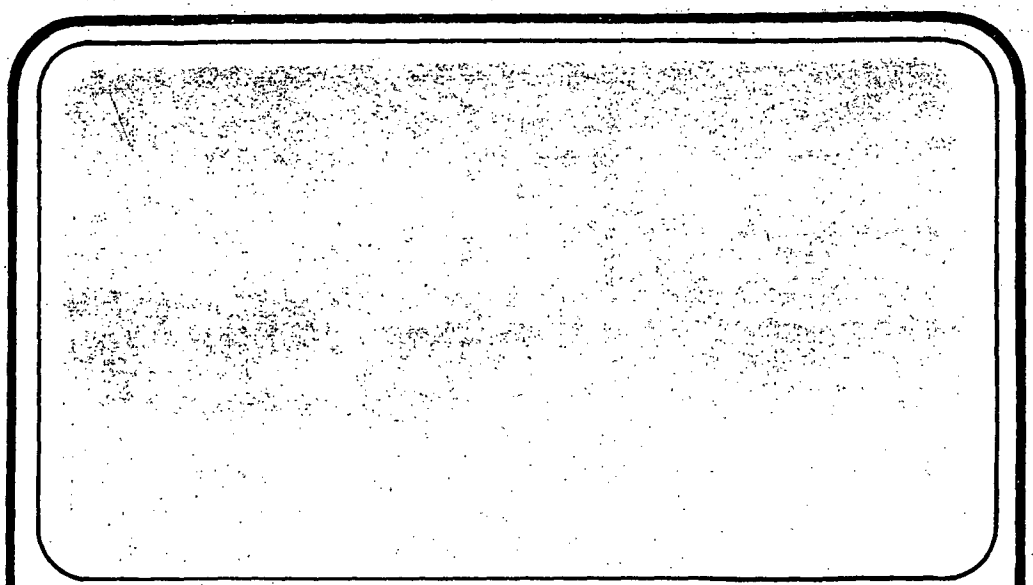
LOCKHEED

253518

PMS REDUNDANCY RATIONALE

DUAL PROCESSOR PROVIDES:

- FULL GN&C BACKUP WITH NO DEGRADATION OF PERFORMANCE MONITORING
- EXPANSION NECESSARY FOR FULL PAYLOAD MONITORING CAPABILITY
- SINGLE FAILURE WITHOUT LOSS OF FUNCTION-DEGRADATION IN SPEED ONLY



Checkout and Ground Support

ACS Avionics Review

CHECKOUT BASELINE REQUIREMENTS

① FLIGHT TEST STATION → PAYLOAD MANAGEMENT

② MAINTENANCE/ANOMALY RECORDER

③ FLIGHT RECORDER

④ SERIAL DIGITAL U/D LINK FOR GROUND AND FLIGHT CHECKOUT

⑤ CHECKOUT STATION INTERFACE

⑥ GSE COMMONALITY

⑦ MAXIMUM USE OF BUILT IN-TEST

LOCKHEED

253601

PAYLOAD MANAGEMENT INTERFACE

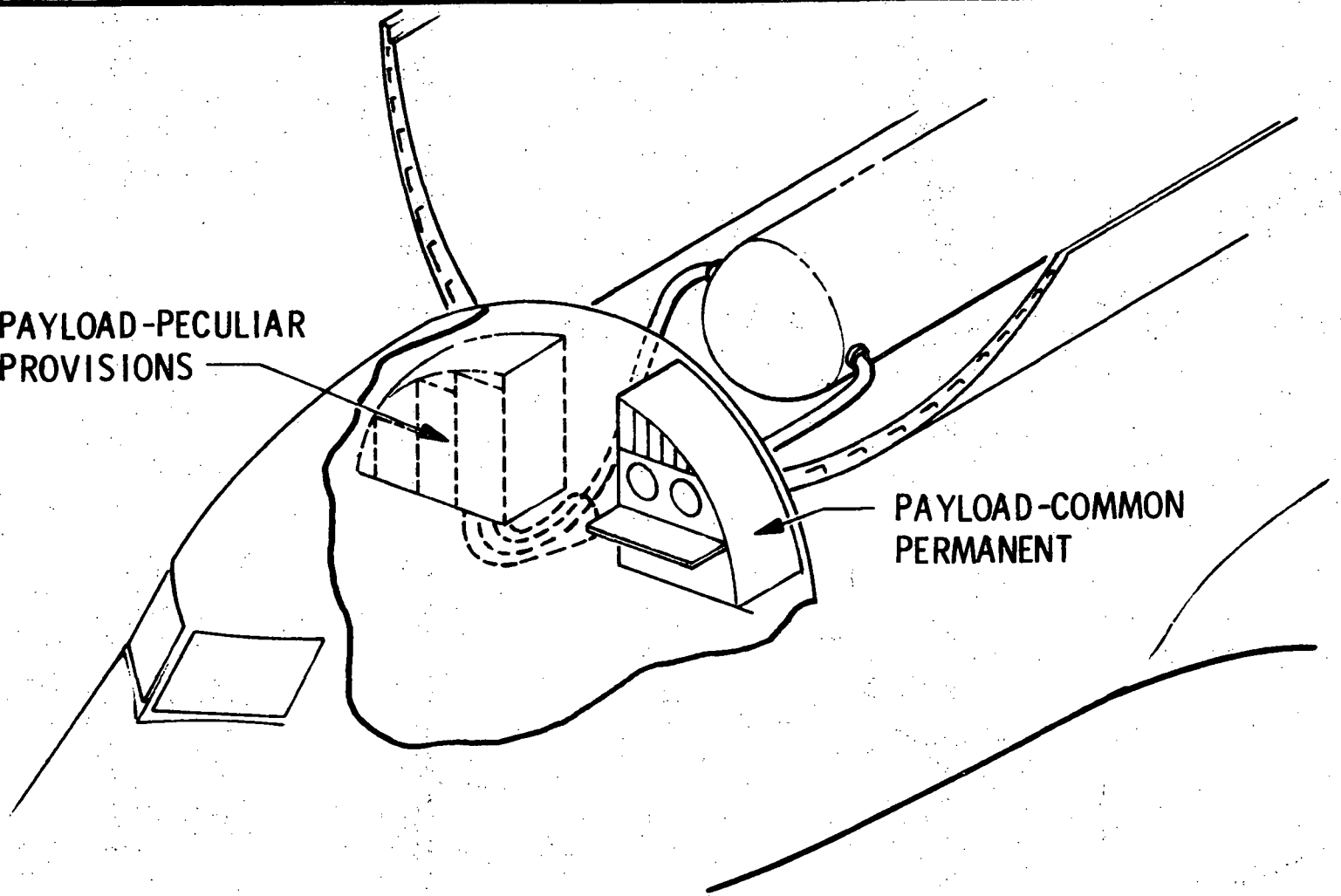
REQUIREMENT: PROVIDE PAYLOAD MANAGEMENT CHECKOUT SUPPORT

ISSUE	OBJECT	RECOMMENDATION
PERMANENT STATION VS PROVISIONS FOR PAYLOAD PECULIAR	MINIMIZE RECURRING COSTS	PERMANENT ELEMENTS FOR 70-90 PERCENTILE PROVISIONS TO ACCEPT PL PECULIAR ELEMENTS

LOCKHEED

253602

PAYLOAD MANAGEMENT INTERFACE



253603

LOCKHEED

PAYLOAD/ORBITER INTERFACE IMPACT

SERVICE	CAPABILITY	IMPACT
DATA STORAGE		
CORE	10K WORDS	–
OFFLINE	10K WORDS	–
	1.5M WORDS	CASSETTE
DRUM	TBD (~10K WORDS)	–
COMPUTER OPERATIONS		
ASCENT	0-10K/SEC	PRIORITY
ORBIT	10K/SEC	–
THRUPUT TO EARTH	10K B/SEC	–

LOCKHEED

253604

PAYLOAD/ORBITER INTERFACE IMPACT (CONT)

SERVICE	CAPABILITY	IMPACT
ELECT. PWR		
ASCENT	15 KW AV 1.0 KW PK	1.3 LB/KWH
ORBIT	19 KW AV 6 KW PK	1.3 LB/KWH
CREW DISPLAY		
C&W	30 ANNUNCIATORS	–
STATUS	76 CHARACTERS	–
INSTRUCTIONS	1570 CHARACTERS	–

LOCKHEED

253605

PAYLOAD/ORBITER INTERFACE IMPACT (CONT)

SERVICE	CAPABILITY	IMPACT
VOLUME		
PERMANENT		
EQUIPMENT	5.6 FT^3	219 LB
CABLES SUPPORT AND ACCESS	11.0 FT^3	162 LB
GROWTH	4.2 FT^3	–
SUBTOTAL	20.8 FT^3	
PROVISIONS		
EQUIPMENT	14.6 FT^3	–
CABLING AND POWER SUPPLIES	11.0 FT^3	–
SUBTOTAL	25.6 FT^3	
TOTAL	46.4 FT^3	

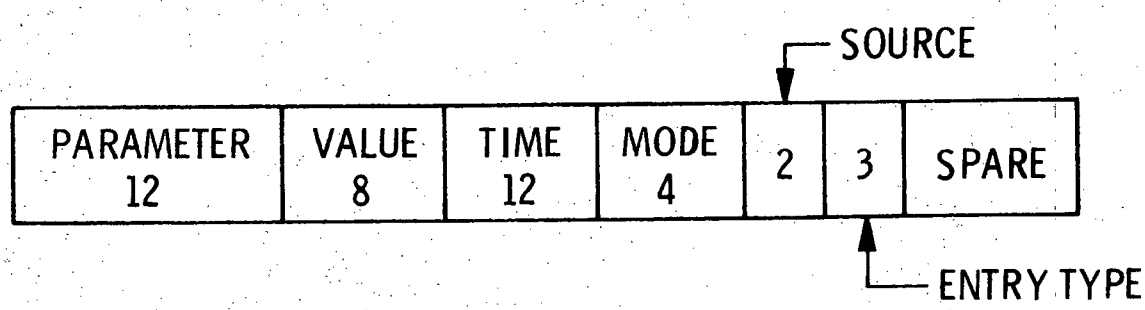
LOCKHEED

253606

MAINTENANCE ANOMALY RECORDER

DATA STORED	QTY OF 48-BIT WORDS
FAILURE/MALFUNCTION	303
REALTIME TREND ALARMS	758
POST-FLIGHT TREND DATA	300,000
TOTAL	301,061

13% OF PMS BASELINE CAPACITY



LOCKHEED

253607

FLIGHT RECORDER

CAPACITY

7-TRACK, 1/2-INCH TAPE

AREA MICROPHONE

15 CHANNELS (5 AT 10 SPS, 10 AT 1 SPS)*

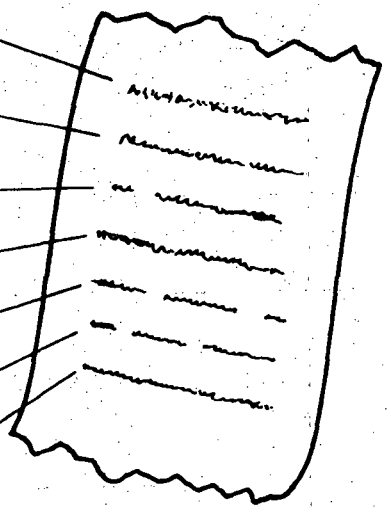
PILOT VOICE

CLOCK

COPILOT VOICE

PMS DATA*

PAYLOAD MONITOR VOICE



*64 WORDS/FRAME/SEC

LOCKHEED

253608

FLIGHT RECORDER (CONT)

INPUT DATA

5 CHANNELS AT 10 SAMPLES/SEC

70 CHANNELS AT 1 SAMPLE/SEC

STORAGE TIME

30 MINUTES – 150 FT LOOP

PLAYBACK

5-MINUTE DUMP AT 6:1 SPEED

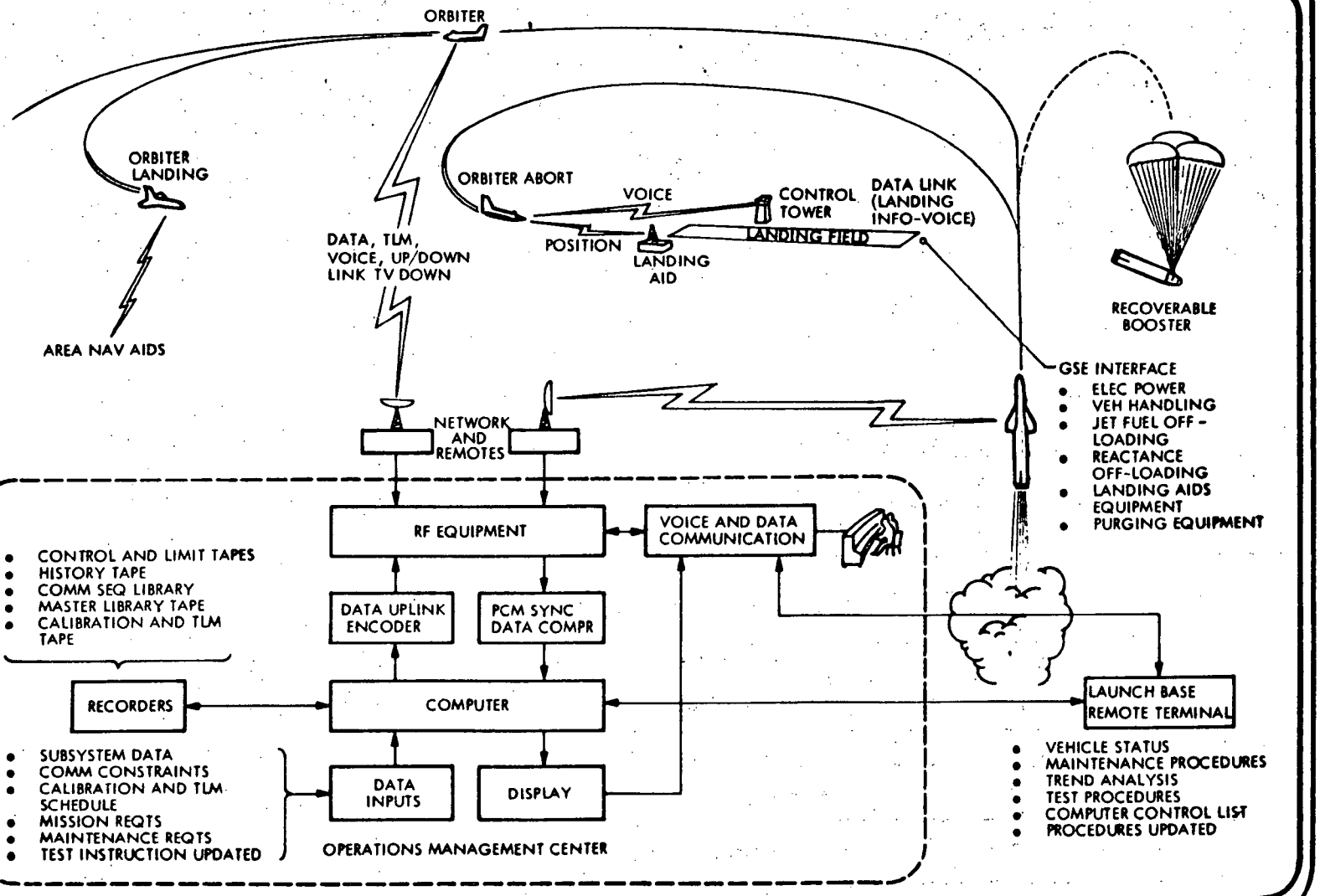
RECOMMEND PLAYBACK BE LIMITED TO GROUND OPERATION FOR 100% FLIGHT COVERAGE

LOCKHEED

253609

GROUND SUPPORT/VEHICLE MISSION INTERFACE

FLOW DIAGRAM

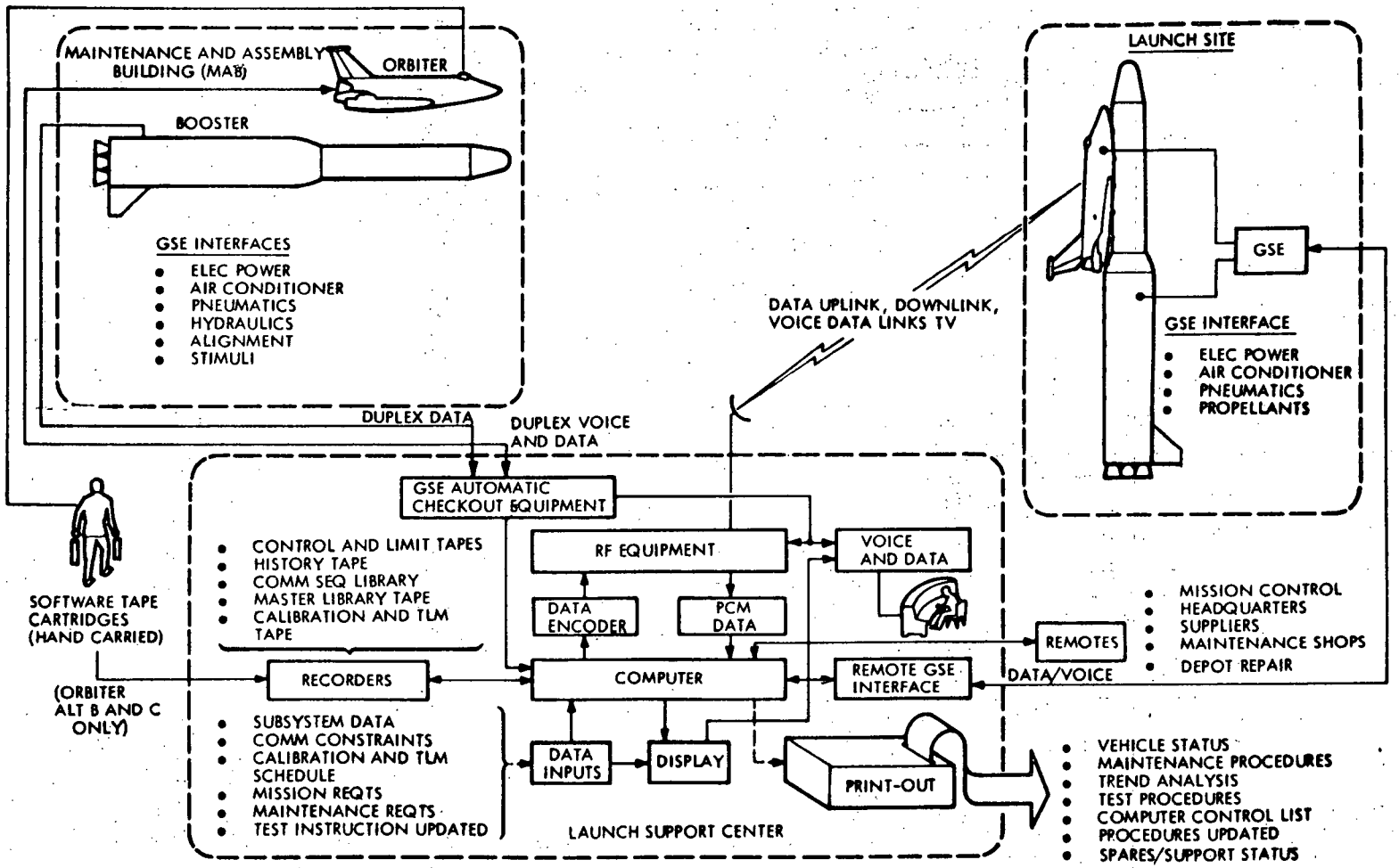


LOCKHEED

253632

GROUND SUPPORT/VEHICLE CHECKOUT INTERFACE

FLOW DIAGRAM



LOCKHEED

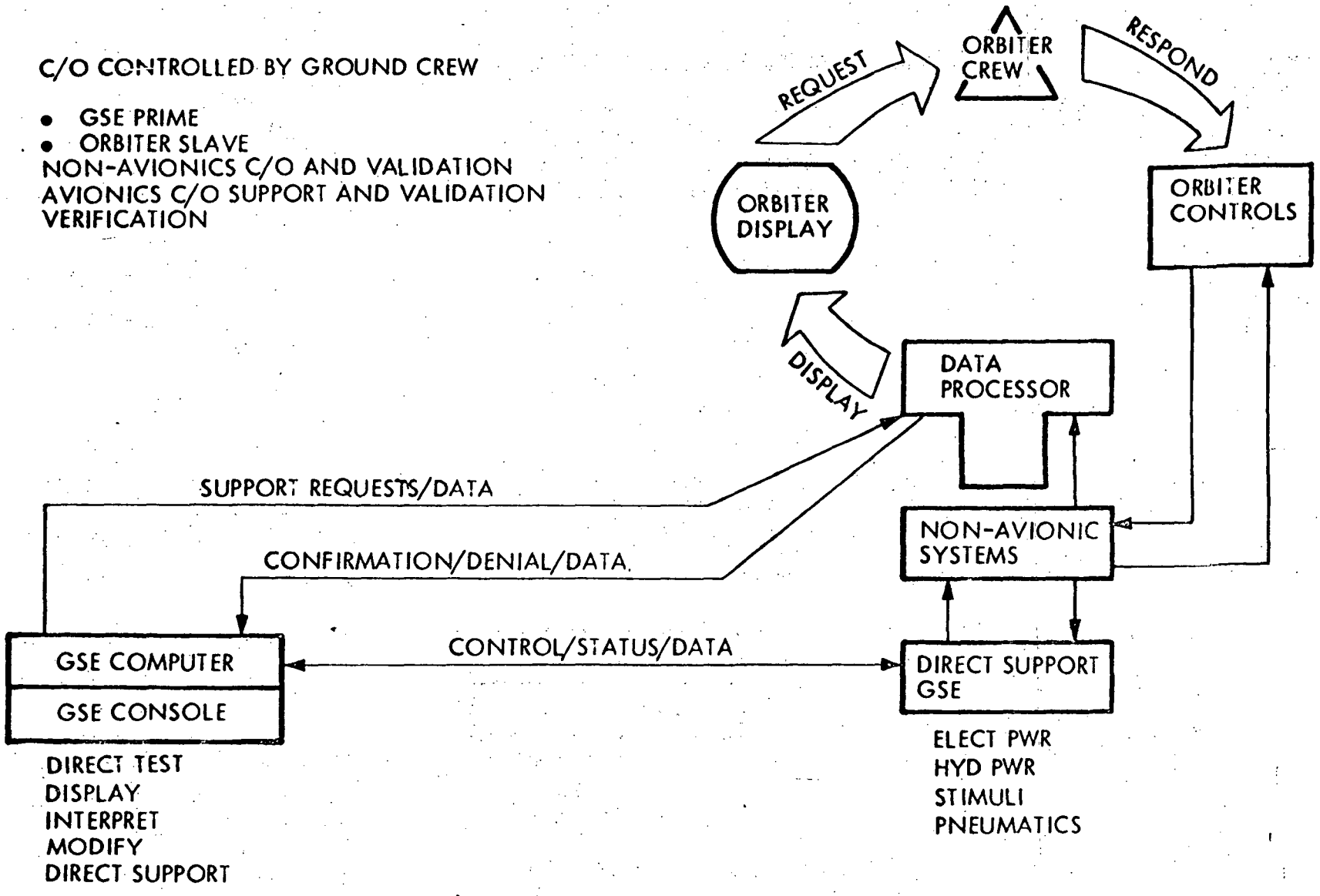
253631

CHECKOUT STATION/GSE INTERFACE-MODE I

C/O CONTROLLED BY GROUND CREW

- GSE PRIME
- ORBITER SLAVE

NON-AVIONICS C/O AND VALIDATION
AVIONICS C/O SUPPORT AND VALIDATION
VERIFICATION



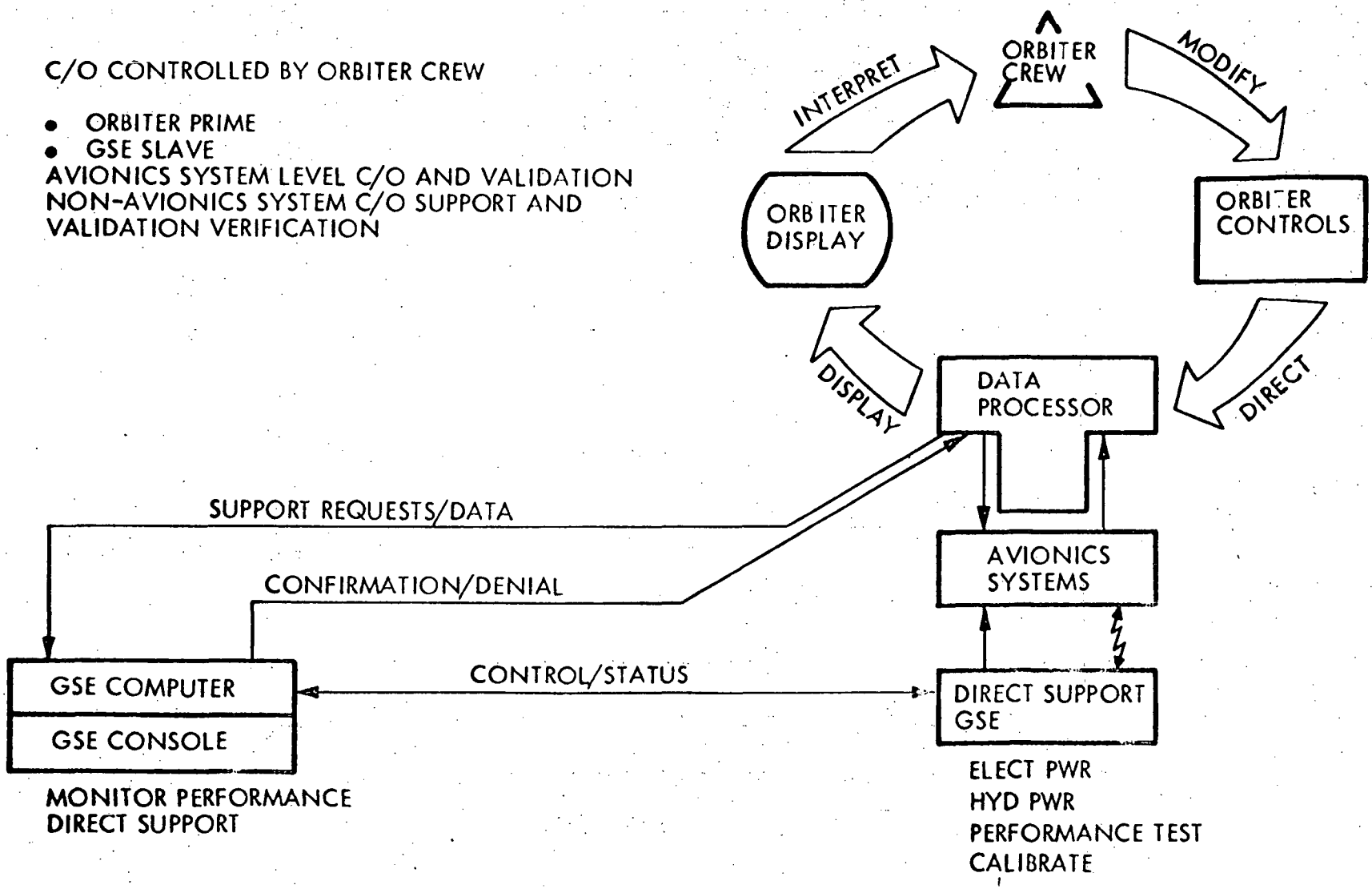
233806

CHECKOUT STATION/GSE INTERFACE-MODE II

C/O CONTROLLED BY ORBITER CREW

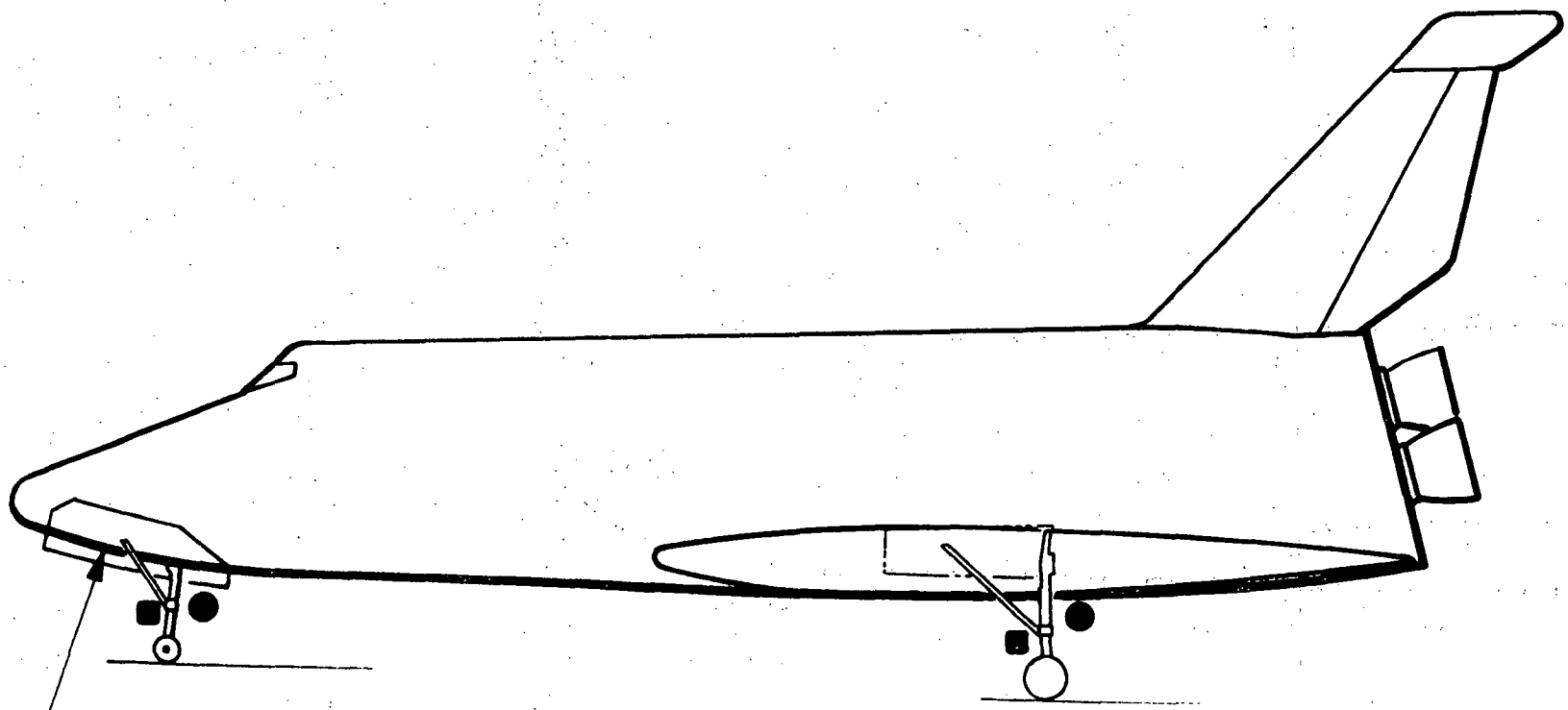
- ORBITER PRIME
- GSE SLAVE

AVIONICS SYSTEM LEVEL C/O AND VALIDATION
NON-AVIONICS SYSTEM C/O SUPPORT AND VALIDATION VERIFICATION



233807

GSE INTERFACE - HORIZONTAL



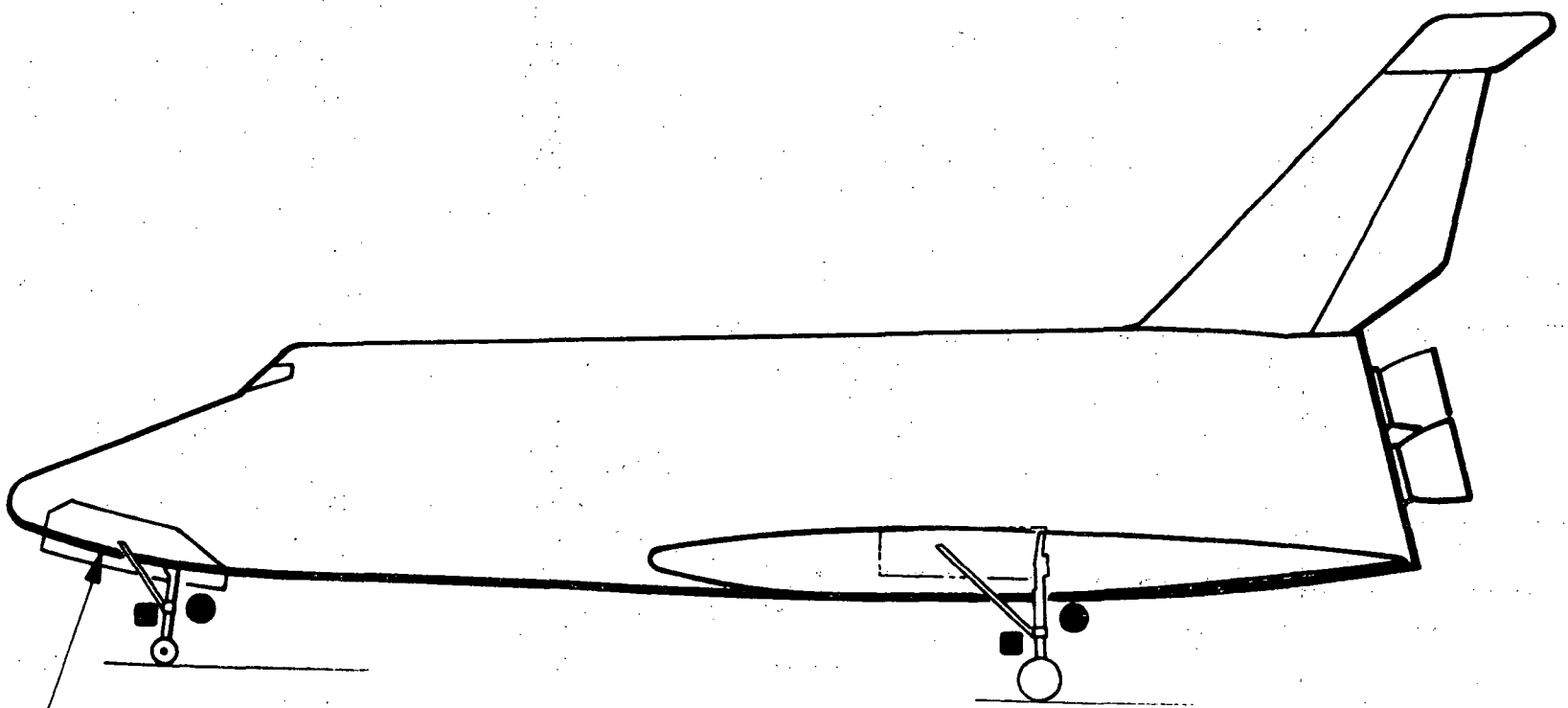
+ 28 VDC UMBILICAL
115 VAC, 400 , 3 PHASE UMBILICAL
DATA LINK CONNECTORS
UNIFIED S-BAND CONNECTOR
AIR CONDITIONING DUCT
INTERCOM STATION

● STATIC GROUND
■ INTERCOM STATION

LOCKHEED

253612

GSE INTERFACE - HORIZONTAL



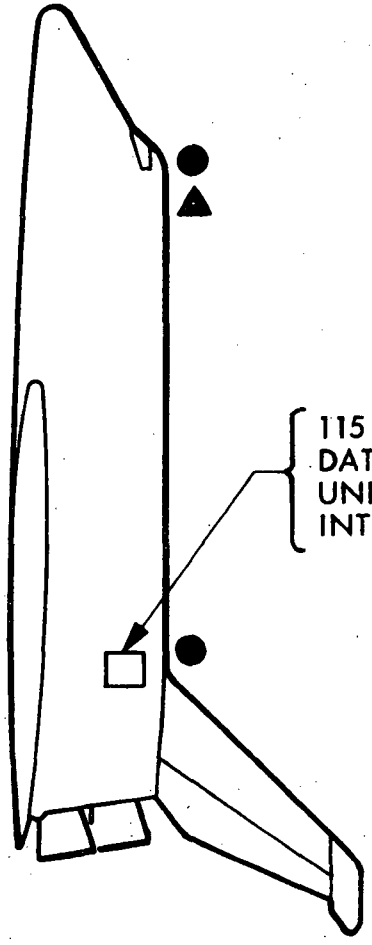
+ 28 VDC UMBILICAL
115 VAC, 400 , 3 PHASE UMBILICAL
DATA LINK CONNECTORS
UNIFIED S-BAND CONNECTOR
AIR CONDITIONING DUCT
INTERCOM STATION

● STATIC GROUND
■ INTERCOM STATION

LOCKHEED

253612

GSE INTERFACE – VERTICAL



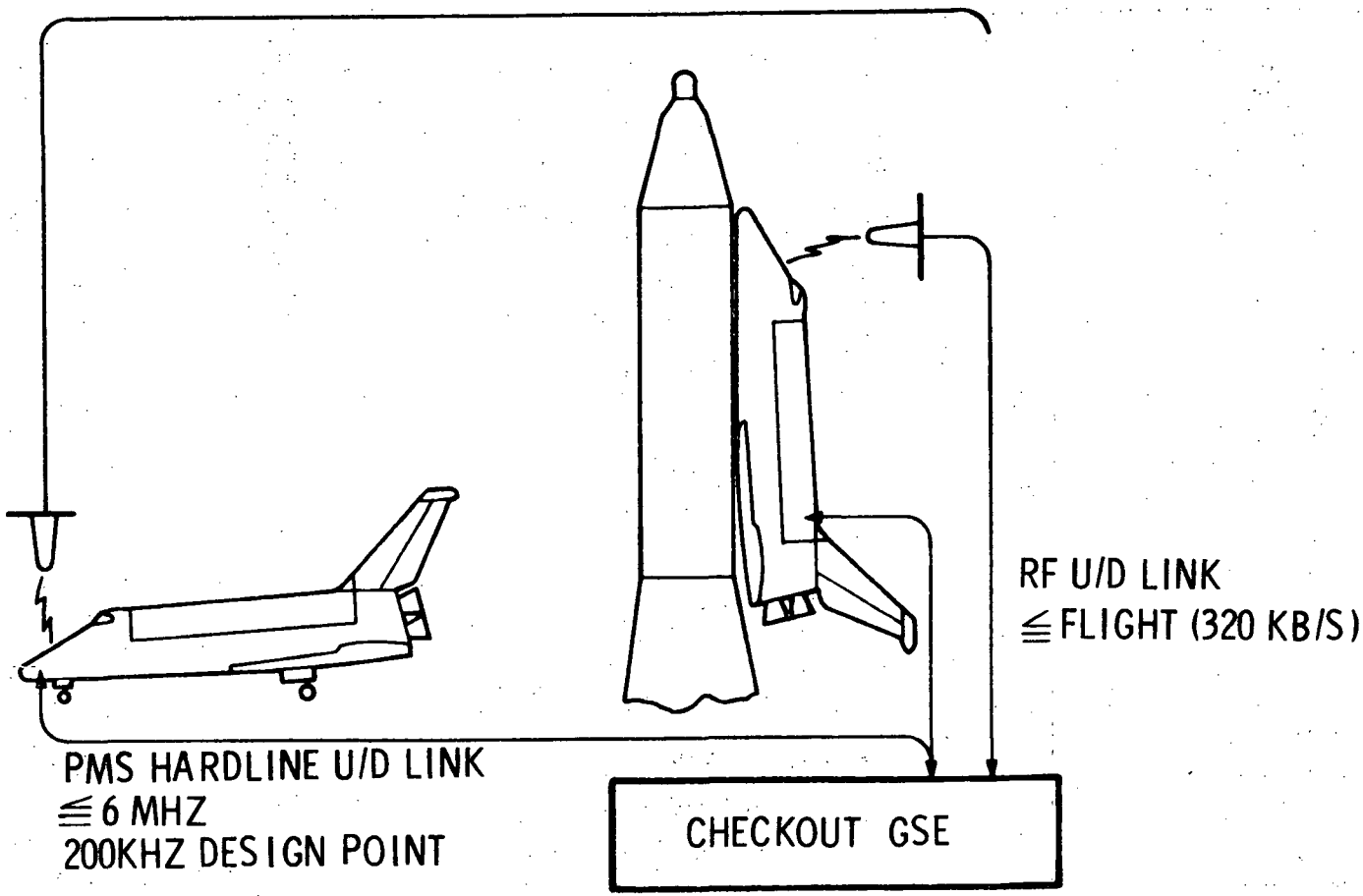
115 VAC, 400 ~, 3 PHASE CONNECTOR
DATA LINK CONNECTORS
UNIFIED S-BAND CONNECTOR
INTERCOM STATION

● STATIC GROUND
▲ AIR CONDITIONING DUCT

LOCKHEED

253613

GROUND CHECKOUT U/D LINK

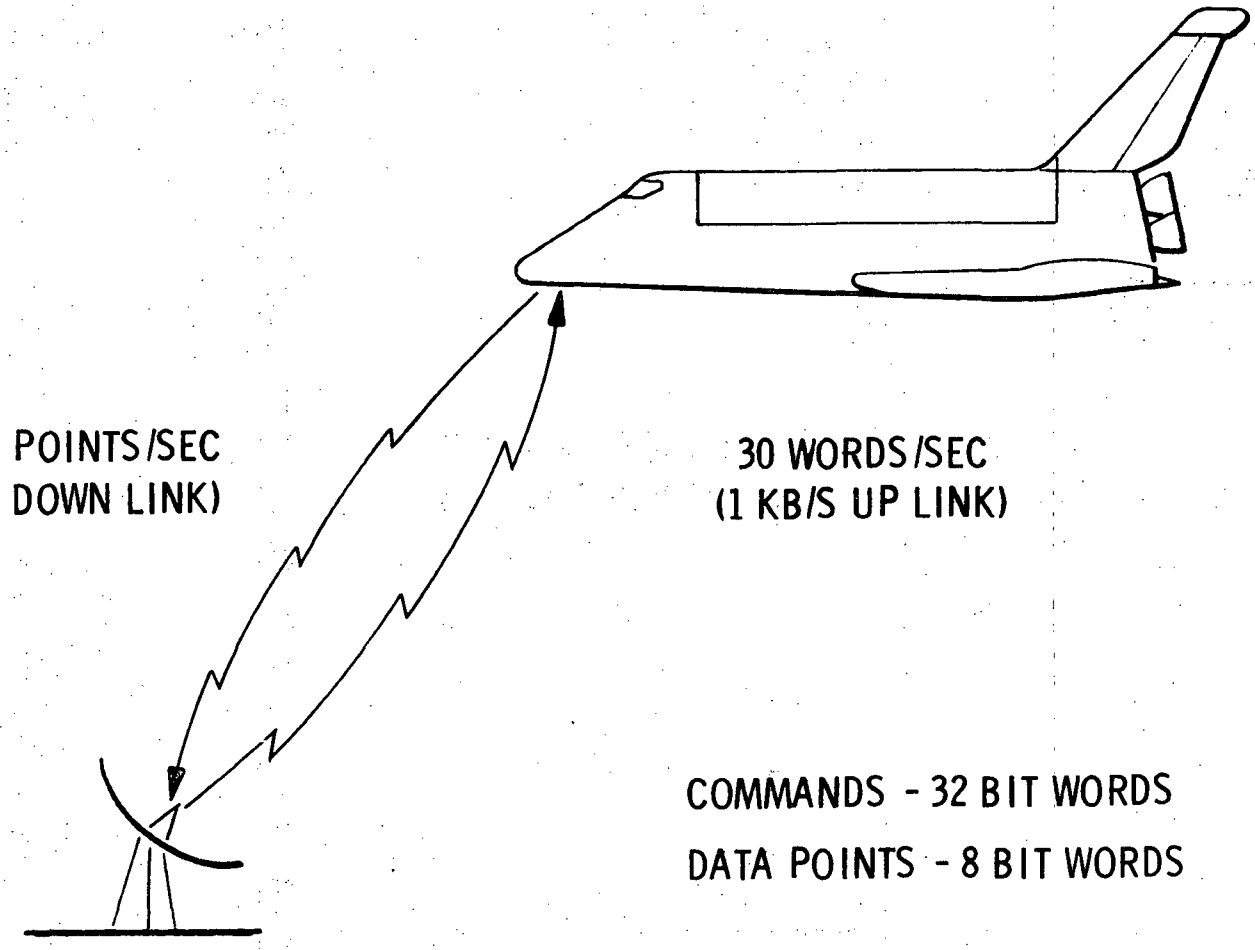


TLM HARD LINE U/D LINK ≦FLIGHT (320 KB/S)

LOCKHEED

253611

FLIGHT CHECKOUT U/D LINK



40K DATA POINTS/SEC
(320 KB/S DOWN LINK)

30 WORDS/SEC
(1 KB/S UP LINK)

COMMANDS - 32 BIT WORDS

DATA POINTS - 8 BIT WORDS

LOCKHEED

253610

GSE COMMONALITY

EQUIPMENT SOURCE	QTY	% (WT)	EXISTING GSE	NEW GSE
S-3A	43	40	VAST	N/A
C-5A L-1011 C-141 747 AH-56 APOLLO P-3V	118	33	UNITS	N/A
AGENA	8	8	ATE & UNITS	(USE VAST)
NEW	71	19	N/A	MAKE VAST COMPATIBLE

LOCKHEED

253616

GSE COMMONALITY (CONT)

GSE TYPE / APPLICATION	AVAILABLE		NEW	
	DEDICATED UNIT	GENERAL PURPOSE	DEDICATED UNIT	GENERAL PURPOSE
DEVELOPMENT	N/A	N/A	TEST TOOL	N/A
MANUFACTURING	ALL	VAST FOR LARGE S/S	HARD TEST TOOL	N/A
INTEGRATION FACILITY	ALL	VAST	VEHICLE PECULIAR	N/A
VEHICLE SUPPORT				
LAUNCH	MOD REQD	N/A	TRADE	
MAINTENANCE	MOD REQD	N/A	TRADE	
EQUIPMENT SUPPORT				
LAUNCH SITE	ALL	VAST (S3A)	N/A	TRADE
OVERHAUL CENTER	ALL	VAST (S3A)	N/A	TRADE

LOCKHEED

253617

BITE UTILIZATION SUMMARY

	QTY LRUs	BITE C/O	SOFTWARE C/O	MANUAL C/O	PERCENT BITE
C/D ELEMENTS	100	4	0	96	4
UNITS (BOXES)	200	89	92	19	44
UNITS (S/C AND XDCRS)	980	0	980	0	0
PERCENT	-	7	84	9	-

233809

SWITCH/CB – CONTROL/MONITORING

ESTIMATED QUANTITIES		MANUAL ACTUATE * (MIN)
PUSHBUTTON (83% LIGHTED)	168	~9
ROTARY	21	~5
TOGGLE	34	~5
PRESS-TO-TEST (INCL C&W)	402	~2
KEYBOARDS (149 KEYS)	3	~8
PROPORTIONAL CONTROLS	12	~12
CIRCUIT BREAKERS (MANUAL)	300	~15
	TOTAL	56

*MANUAL ACTUATION TO PMS CUE

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253619

SWITCH/CB CONTROL/MONITORING

REMOTE CHECKOUT

NONRECURRING		
DEVELOP 7 SWITCH TYPES ($40K EA)	=	$280K
MODIFY AND QUALIFY 14 PANELS ($20K EA)	=	280K
INSTALLATION FIRST VEHICLE (150 MH/ITEM) (940 ITEMS – 2820 POINTS)	=	2.4M
SUBTOTAL		$2.96M
RECURRING		
4 VEHICLES AT 1/2 FIRST VEHICLE	=	$4.8M
TOTAL		$7.76M

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25362C

SWITCH/CB CONTROL/MONITORING

MANUAL CHECKOUT

MANUAL C/O LABOR

2 TEST/FLIGHT – 2 MEN AT 2 HR/TEST FOR 445 FLIGHTS	$60.5K

SOFTWARE

30K WORD PROGRAM AT $100/WORD	$ 3M
TOTAL	$ 3.605M

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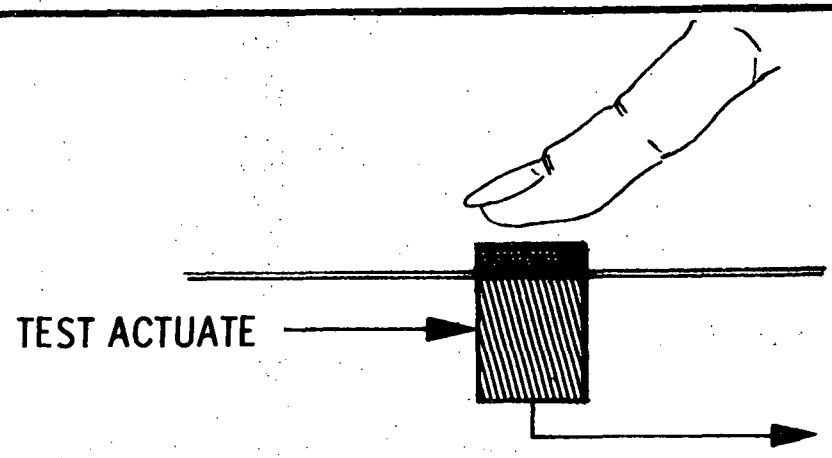
253620A

SWITCH/CB CONTROL/MONITORING

OPERATIONAL ACTUATE



ESSENTIAL MANUAL FUNCTION NOT VERIFIED BY AUTOMATIC TEST

SAFETY NOT IMPROVED

COST EFFECTIVITY

- COMPUTER PROMPTED MANUAL TEST $3.6M
- AUTOMATIC REMOTE TEST $7.8M

RECOMMEND – MANUAL TEST UNDER COMPUTER CONTROL

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253621

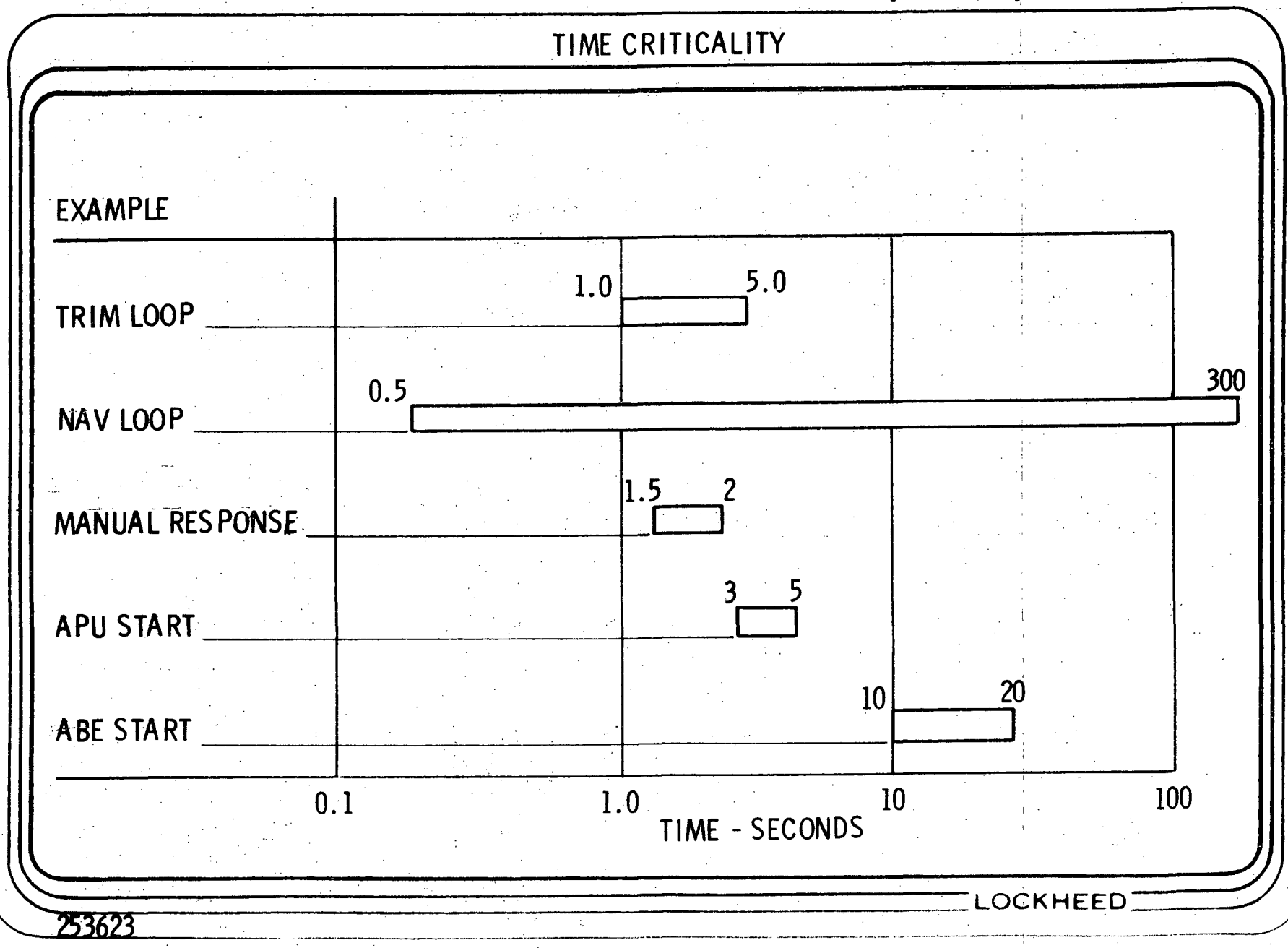
REDUNDANCY MANAGEMENT

KEY FACTOR AFFECTING REDUNDANCY MANAGEMENT TECHNIQUE IS TIME CRITICALITY

TIME CRITICALITY IS CHARACTERIZED BY INERTIA (LONG TIME CONSTANT)

EXAMPLES – APUs, SMOOTHING ALGORITHMS, AND TRIM (ERROR INTEGRATION)

REDUNDANCY MANAGEMENT (CONT)



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253623

REDUNDANCY MANAGEMENT (CONT)

	HARDWARE	HARDWARE/SOFTWARE	SOFTWARE
TIME NOT CRITICAL	• BIT WARNING • CREW AWARENESS • CREW CORRECTIVE ACTION	• BIT WARNING WITH SOFTWARE CORRECT AND CREW WARNING • LOGIC EVALUATION OF MULTIPLE SIGNALS • END-TO-END PERFORMANCE EVALUATION	• REALTIME TRENDING • LOOP TEST-TO-CHECK CPU MEMORY I/O • OFFLINE TEST UNDER CREW CONTROL
TIME CRITICAL	• MAJORITY VOTING • AVERAGING • MEDIAN SELECT	• ALTERNATE HARDWARE SELECT ON BASIS OF COMPUTER MODEL	• CREDIBILITY TEST PRIOR TO EXECUTE FOR FALSE OUTPUT INHIBIT • WATCHDOG TIMER TO INITIATE ALTERNATE SOLUTION • GHOSTING WITH ALTERNATE COMPUTATIONAL PATH

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253624

REDUNDANCY SELECTION

REDUNDANCY DEVELOPED IN EACH SUBSYSTEM

REDUNDANCY LEVEL DETERMINED WITH AEROSPACE CORP. COMPUTER PROGRAM (SYSEFF)

FAIL-OPERATIONAL IS MINIMUM REDUNDANCY FOR FLIGHT CRITICAL

SYSEFF IN USE AT LMSC SINCE 1968 ON OPERATIONAL PROGRAMS

REDUNDANCY SELECTION

SYSEFF PROGRAM OVERVIEW

SUBSYSTEM INPUTS

- MAXIMUM COST
- MAXIMUM WEIGHT
- MAXIMUM VOLUME
- ELEMENT CONFIGURATION

ELEMENT INPUTS

- COST
- WEIGHT
- VOLUME
- FAILURE RATE

LIMITATIONS

- 30 SUBSYSTEMS
- 500 ELEMENTS

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253626

REDUNDANCY SELECTION

SYSEFF CAPABILITY USED

REDUNDANCY CONFIGURATION OPTIMIZATION TO COST, WEIGHT, VOLUME LIMITS

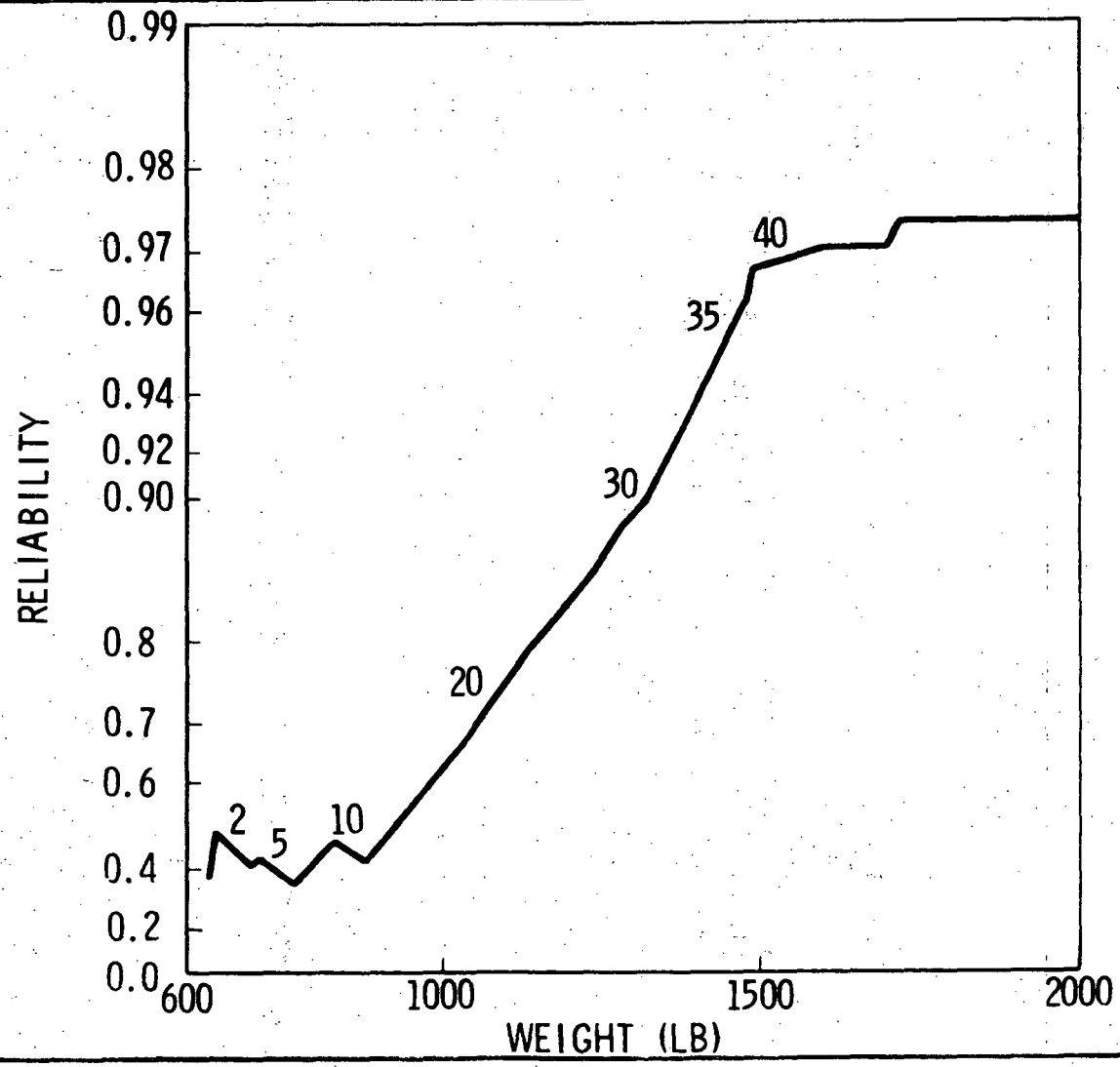
RELIABILITY AS A FUNCTION OF OPERATING TIME

RELIABILITY VS CRITICAL FUNCTION ALTERNATIVES

MACHINE PLOTS

- S/S RELIABILITY VS CONFIGURATION (WT)
- S/S RELIABILITY VS ELAPSED TIME
- S/S EFFECTIVE COST VS CONFIGURATION (WT)

REDUNDANCY SELECTION



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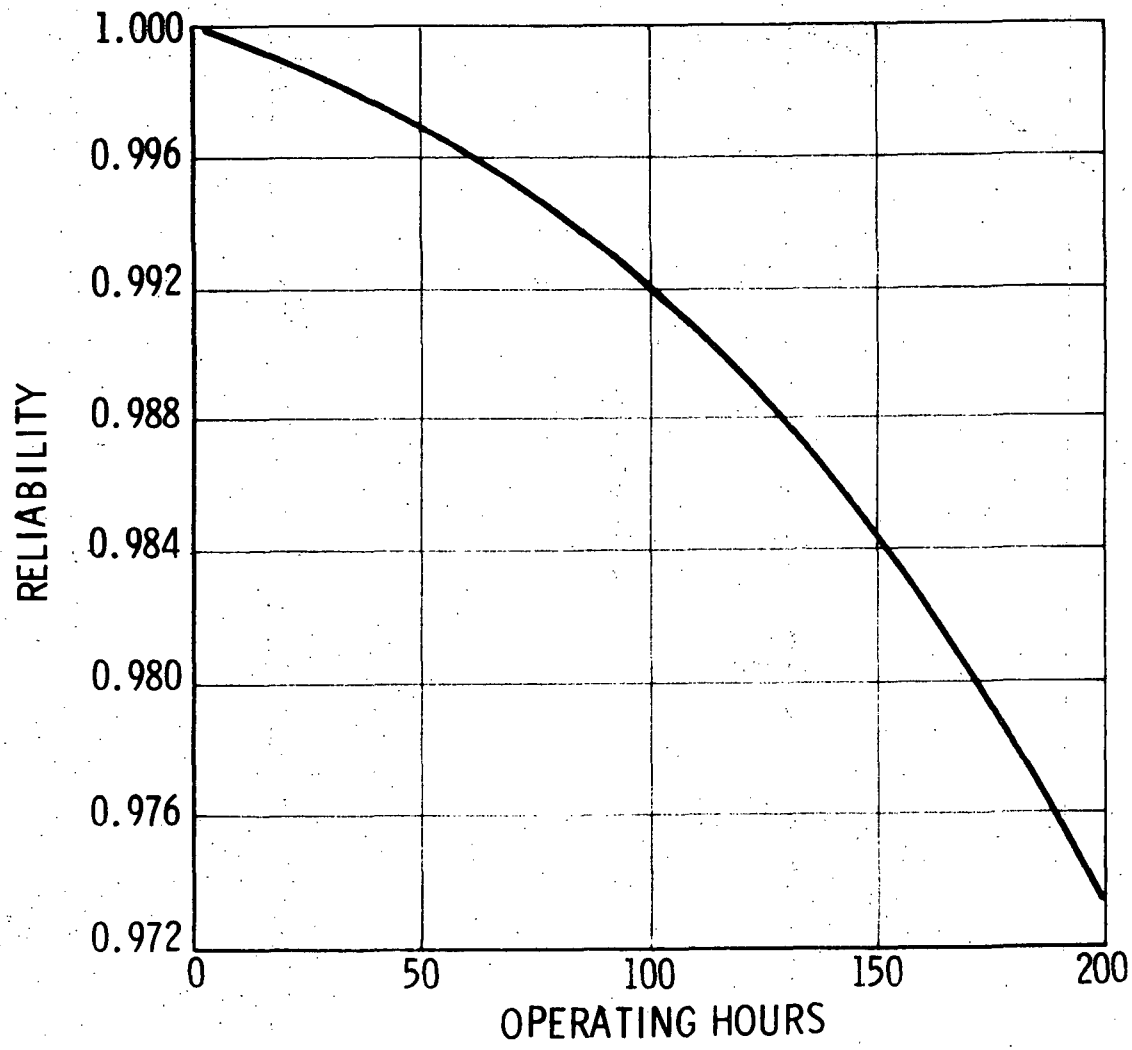
253628

REDUNDANCY SELECTION (CONT)



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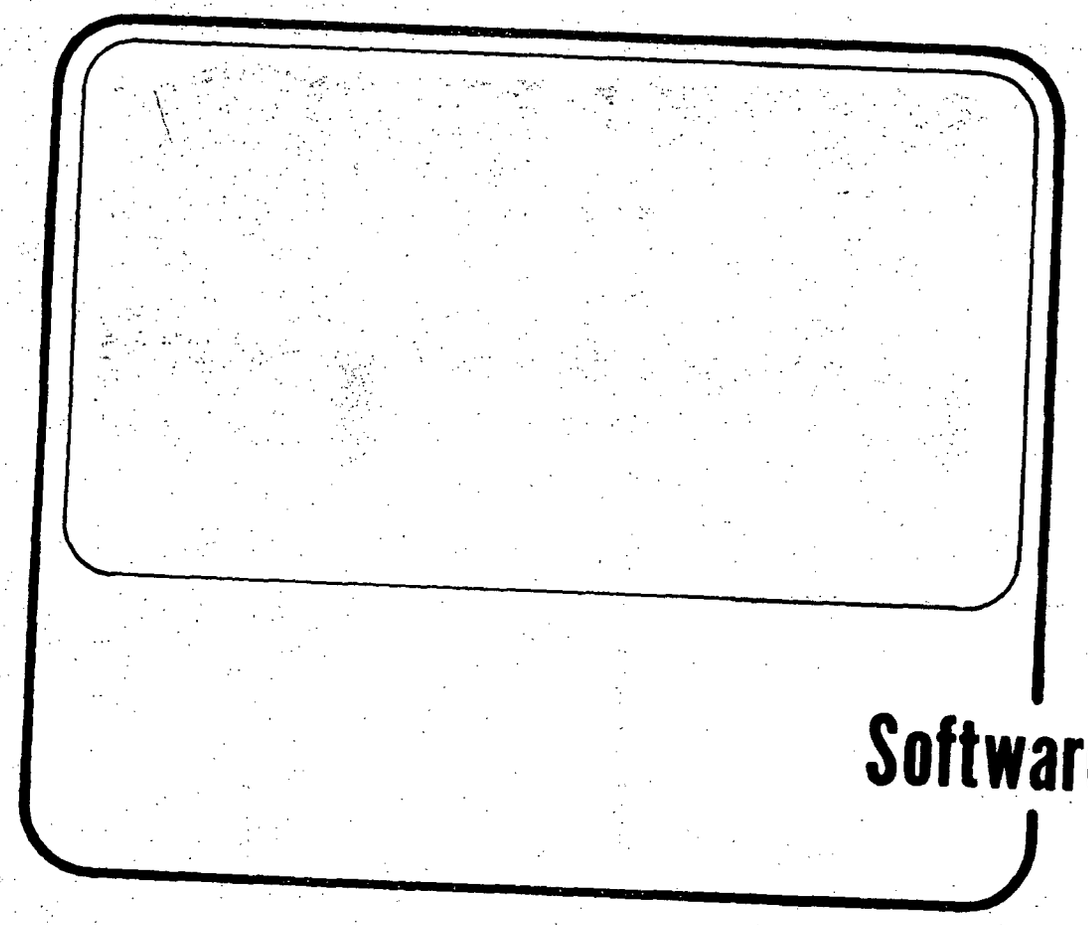
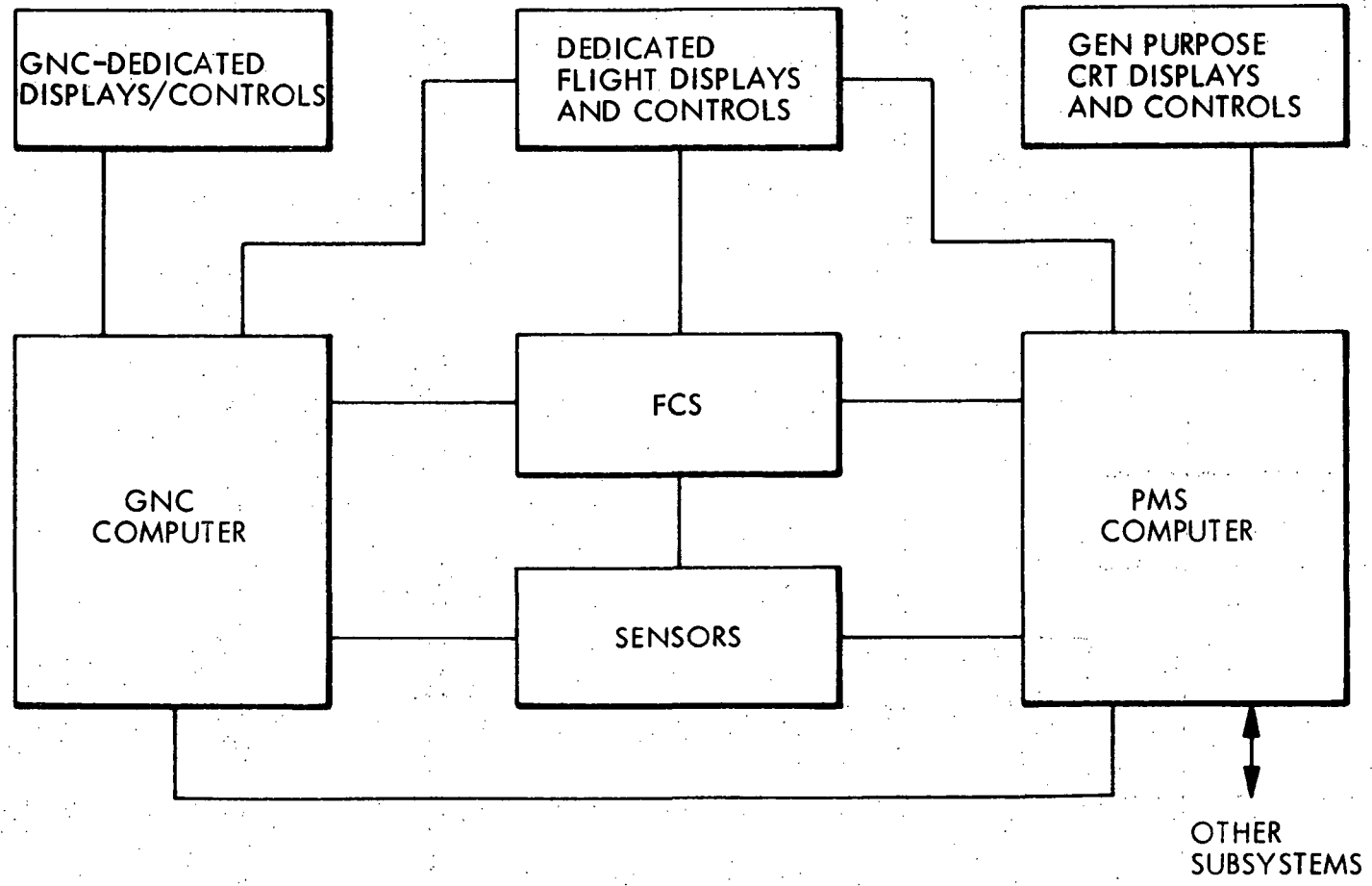
253629



ACS Avionics Review

SOFTWARE-RELATED BASELINE OVERVIEW



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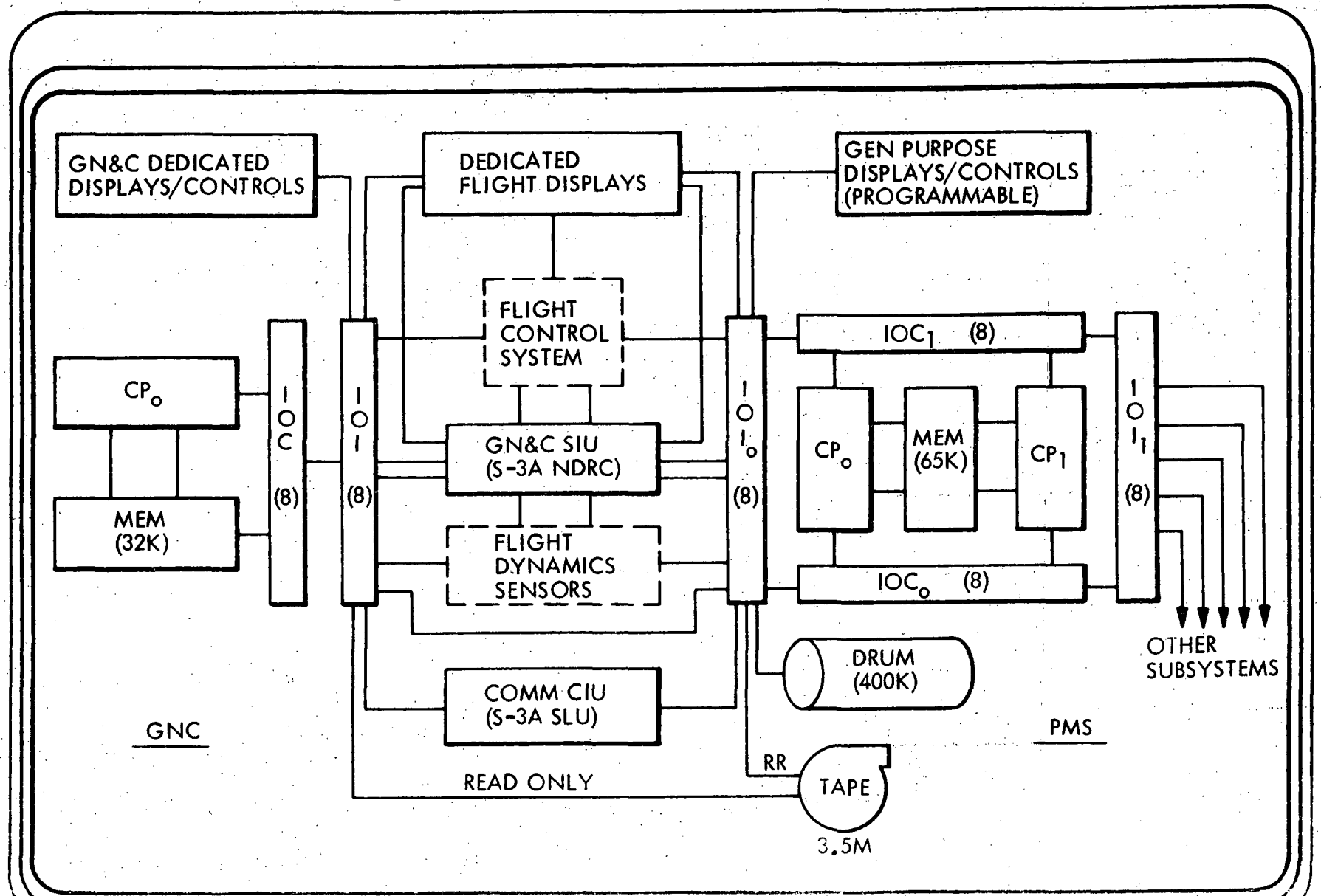
253701

SOFTWARE-RELATED BASELINE CONFIGURATION
ORBITER VEHICLE AVIONICS



BASELINE SOFTWARE FUNCTIONS VS EFFECTIVITY

FUNCTION	HFT	VFT	INITIAL OPS	FINAL OPS
ONBOARD CO/FI AND DATA EXTRACTION	●	0	0	0
INSTRUMENTATION PROCESSING AND CONTROL	●	0	0	0
ABORT AIDS	●	0	0	0
GN&C COMPUTATIONS		●	0	0
ONBOARD CO/FI/RM		●	0	0
SYSTEM MANAGEMENT AIDS		●	0	0
AVIONICS CONFIGURATION CONTROL			●	0
CONSUMABLES MANAGEMENT			●	0
RENDEZVOUS COMPUTATION			●	0
PAYLOAD MANAGEMENT				●
A/C AND S/C FLIGHT CONTROL				●
NONAVIONICS CONFIGURATION CONTROL				●
MISSION PLANNING				●

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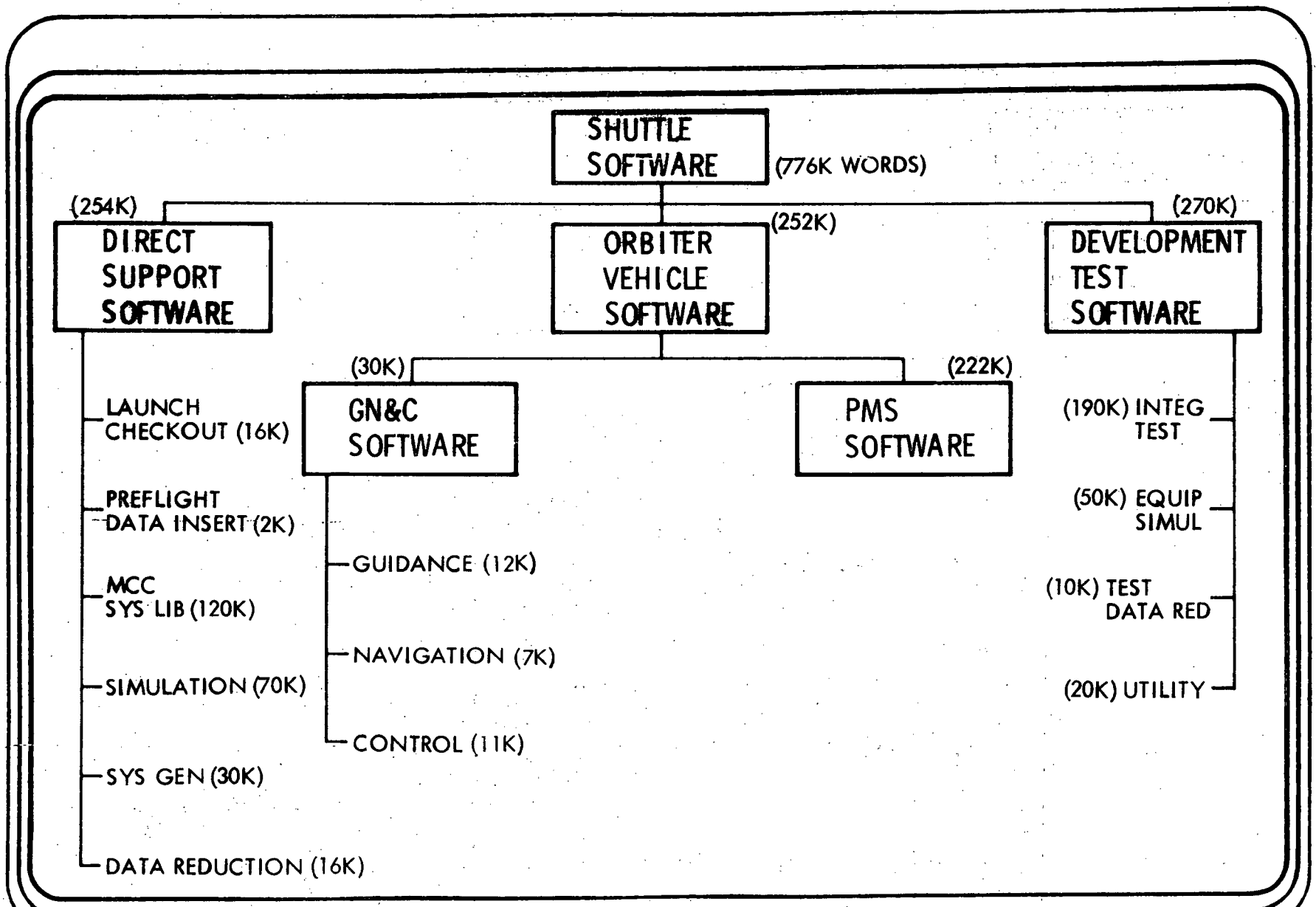
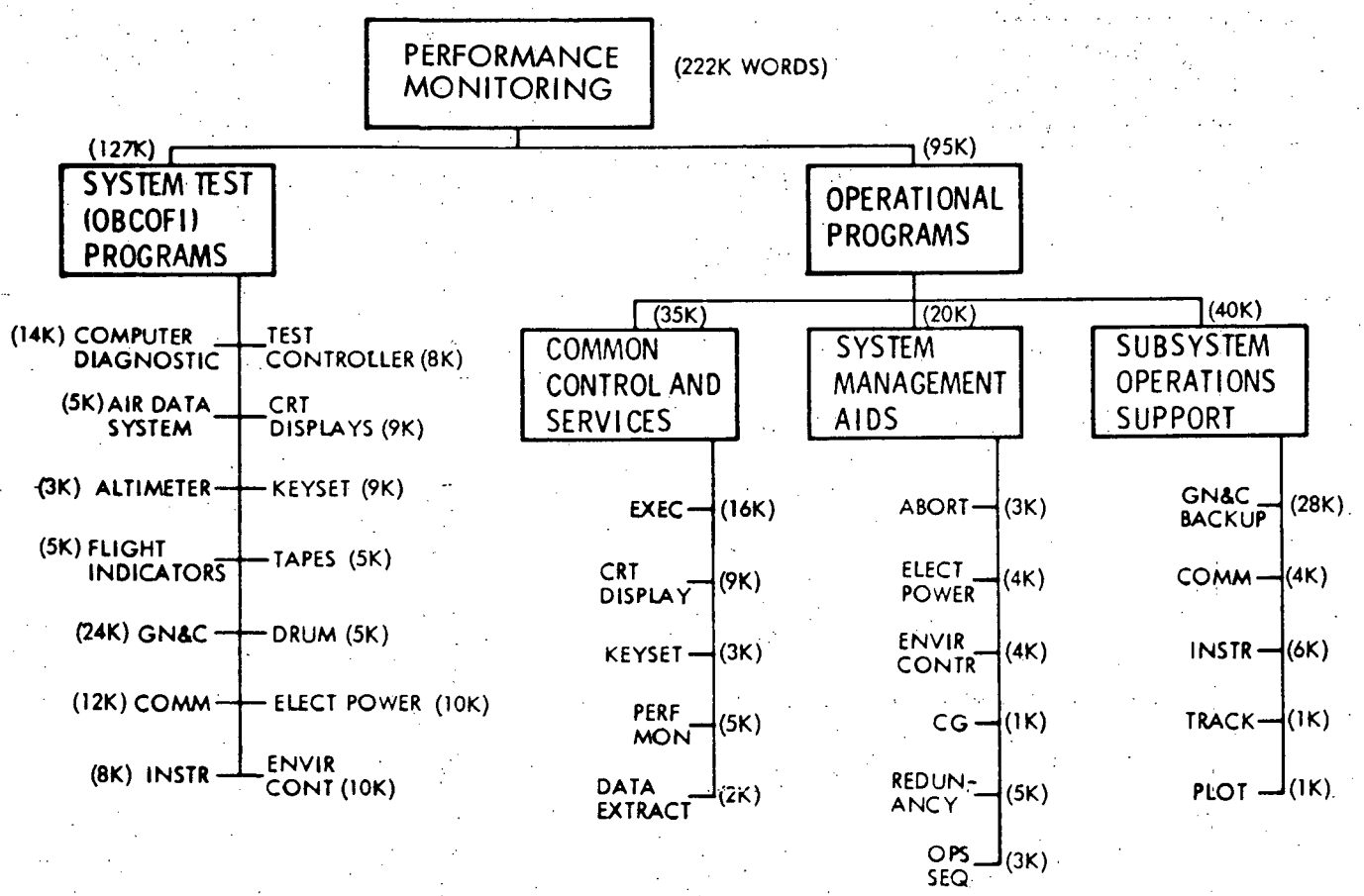
253704

BASELINE SOFTWARE CONFIGURATION



BASELINE SOFTWARE CONFIGURATION



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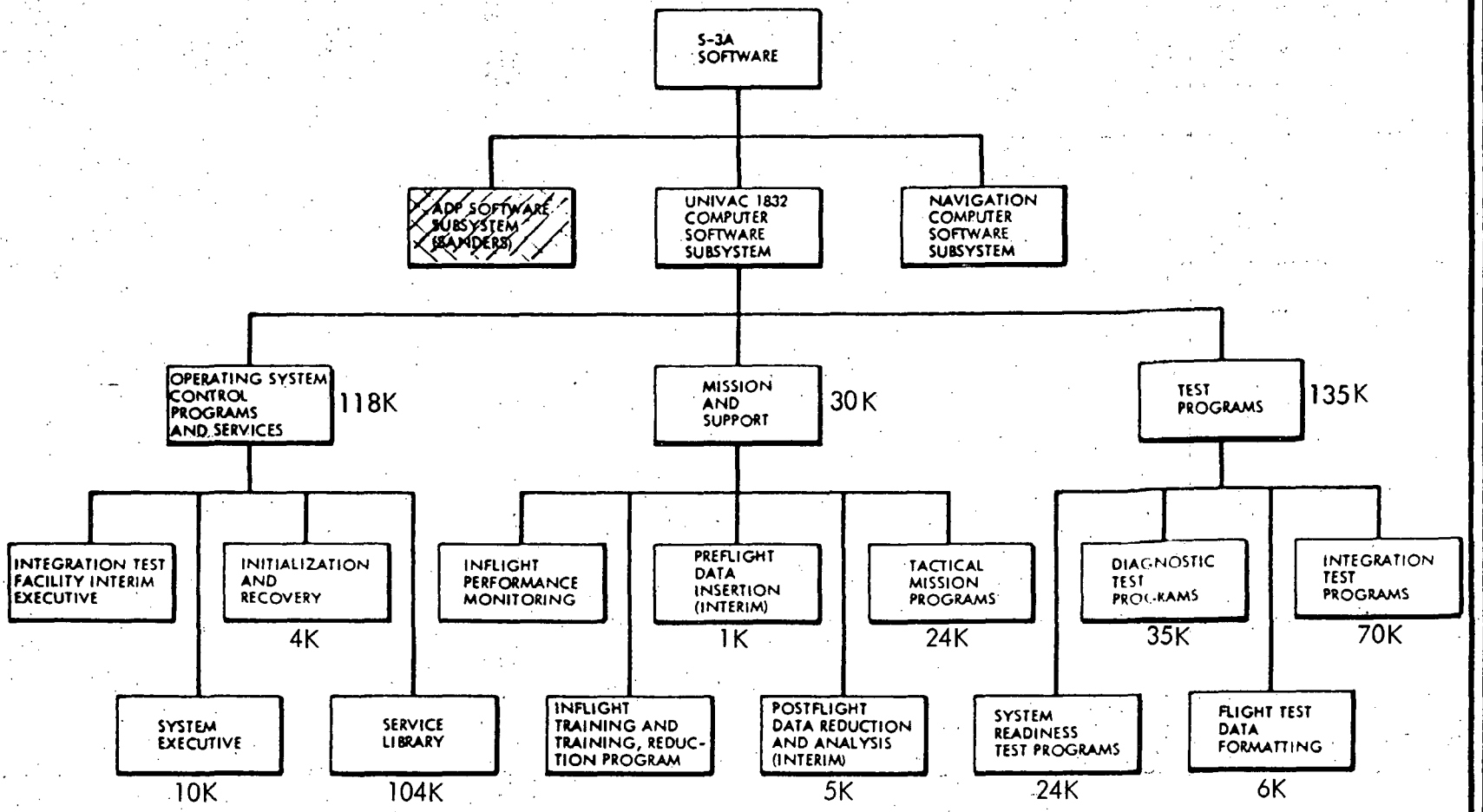
253706

S-3A SOFTWARE HIERARCHY

(EXTENT OF APPLICATION TO SHUTTLE)



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253719

SOFTWARE COST ESTIMATES

	EST SIZE (KW)	COMPARATIVE BASIS	S-3A FACILITIES AND DEPARTURE* EFFECT-IVITY	$ PER WORD	TOTAL $ (M)	OTHER GRD FACILITIES $ PER WORD	TOTAL $ (M)	NEW DEPARTURE $ PER WORD	TOTAL $ (M)
ONBOARD MISSION SOFTWARE	32	S-3A EQUIV + APOLLO	HFT	66	2.1	91	2.9	125	4.0
	125		FMOF	79	9.9	93	11.6	119	14.9
ONBOARD TEST SOFTWARE	127	S-3A EQUIV	ALL	34	4.3	50	6.4	72	9.1
GROUND SYSTEM SOFTWARE	524	S-3A EQUIV + APOLLO	ALL	20	10.6	31	16.4	37	19.5
	683		HFT	24	17.0	38	25.7	48	32.6
	776		FMOF	32	24.8	44	34.4	56	43.5

NOTES:

*1. PER BASELINE; I.E., USE EXISTING S-3A GROUND/ONBOARD COMPUTER-SOFTWARE SYSTEMS AS RECOMMENDED
2. "OTHER FACILITIES" AND "NEW DEPARTURE" ASSUMES SUITABLE EXISTING LANGUAGES AND ASSOCIATED SUPPORT SOFTWARE
3. $PER WORD INCLUDES COMPUTER-HOUR COSTS

HFT Δ = 15.6M
FMOF Δ = 18.7M

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253720

GENERIC SOFTWARE FAILURES-DEFINITIONS

FAILURES WHICH EFFECTIVELY CANCEL REDUNDANCY, I.E., A FAILURE OF ONE OR MORE SOFT LOGIC PROCESSES UPON WHICH REDUNDANT SOFTWARE AND/OR HARDWARE FUNCTIONS ARE DEPENDENT

GENERIC SOFTWARE FAILURES CAN BE

- TRANSITORY
- PERSISTENT
- DETECTED
- UNDETECTED
- RECOVERABLE
- NONRECOVERABLE
- ENVIRONMENT COUPLED
- HARDWARE COUPLED
- CREW (PROCEDURE) COUPLED
- SYSTEM COUPLED
- SINGLE-EVENT DRIVEN
- MULTIPLE-EVENT DRIVEN

GENERIC FAILURE TYPE/SOURCES/AFFECTS

SOURCE \ TYPE	DESIGN/CODING ERROR OR DEFICIENCY	CONTAMINATED DATA AND/OR LOGIC
IDENTICAL REDUNDANT STRINGS	HIGH GENERIC FAILURE POTENTIAL LOWER COST UNIFORM CAPABILITY	IF COMMON DATA SOURCE, GENERIC FAILURE POTENTIAL IS HIGH; OTHERWISE, POTENTIAL IS LOW
DISJOINT REDUNDANT STRINGS	LOW GENERIC FAILURE POTENTIAL HIGHER COST POSSIBLE CAPABILITY VARIATION	
COMPLEX INTERDEPENDENCE	SYSTEM VULNERABLE TO UNANTICIPATED, UNTESTED SEQUENCES AND RESULTS GENERIC FAILURE POTENTIAL HIGH	SYSTEM VULNERABLE REGARDLESS OF DATA SOURCES
COMPLEX CREW INTERACTION	HIGHER COST HIGH FLEXIBILITY	GENERIC FAILURE POTENTIAL HIGH
PROBABLE GENERIC FAILURE ATTRIBUTES	PERSISTENT SINGLE EVENT DRIVEN DETECTABLE NONRECOVERABLE	ALL COMBINATIONS: ENVIRONMENT AND/OR CREW COUPLED

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253710

SOFTWARE FAILURES-APPROACH CONSIDERATIONS

GENERIC FAILURE TYPE/SOURCE	FAILURE CAUSE	APPROACH CONSIDERATIONS		
		DESIGN/DEVELOPMENT	VERIFICATION	REALTIME
IDENTICAL COPIES	DESIGN/CODING DEFICIENCY	DISJOINT IMPLEMENT.	EXTEN. "TEST CASE" STEP-THRU WITH PARAMETER VARIATIONS: • ACTUAL FLT HARDWARE • DYNAMIC LAB (LCF) SIMULATION • CONTROLLED FAULT INSERTION	PMS BACKUP OF CRITICAL GNC FUNCTIONS GNC FAULT TOLERANCE FEATURES: • TIME-OUT/RETRY • FREQ. CHKPTS • REDUNDANT STRINGS PMS MONITORED, GNC SOFTWARE SELF-CHECKS
	CONTAMINATED LOGIC/DATA	FAULT-TOLERANT DESIGNS		
SHARED COMMON ELEMENT	COMMON ROUTINE FAILURE			
	ALTERABLE DATA SET CONTAM.			
COMPLEX INTER-DEPENDENCE	UNTESTED SEQ, BAD LOGIC	MODULARITY, INTERFACE CONTROL		
	NOISE/BAD DATA PROPAGATION			
COMPLEX CREW INTERACTION	UNTESTED/ILLEGAL PROCEDURE	SYSTEM PROTECT. FEATURES, PARTITIONED CREW INTERFACES	ACTUAL-CREW SCENARIOS SPECIAL DATA EXTRACTION	CUE/RESPONSE, "SAFETY" DEFAULTS
	INADVERTENT ACTIONS			
ALL TYPES/SOURCES, AND CAUSES		SIMULATION, REMOTE TERMINALS	BUILT-IN SOFTWARE DEBUG AIDS	ADVANCED ERROR RECOVERY METHODS

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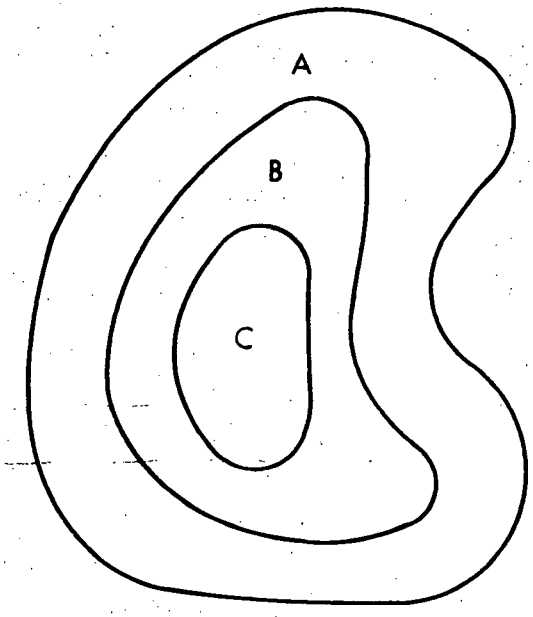
253712

GENERIC FAILURE PREVENTION-VERIFICATION TESTING

TYPICAL



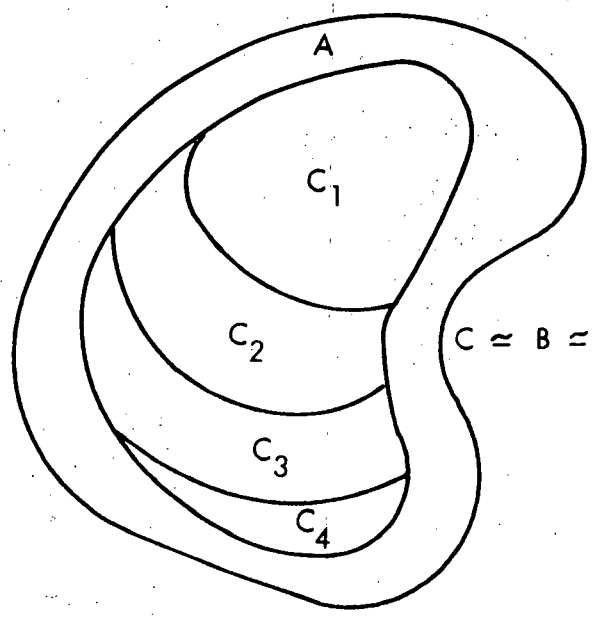
$C \simeq 0.4B \simeq 0.2A$

A = ALL POSSIBLE OPERATIONAL ENVIRONMENTS

B = CONSIDERED IN DESIGN

C = SELECTED FOR TEST

CONSIDER FOR SHUTTLE



$C \simeq B \simeq 0.6A$

$C = C_1 + C_2 + C_3 + C_4 \simeq B$

REASONS:

- BITE-BASED IMS/SIU/LRU MONITOR AND CONTROL
- SOFTWARE DEVELOPMENT APPROACH
- PHASED DEVELOPMENT

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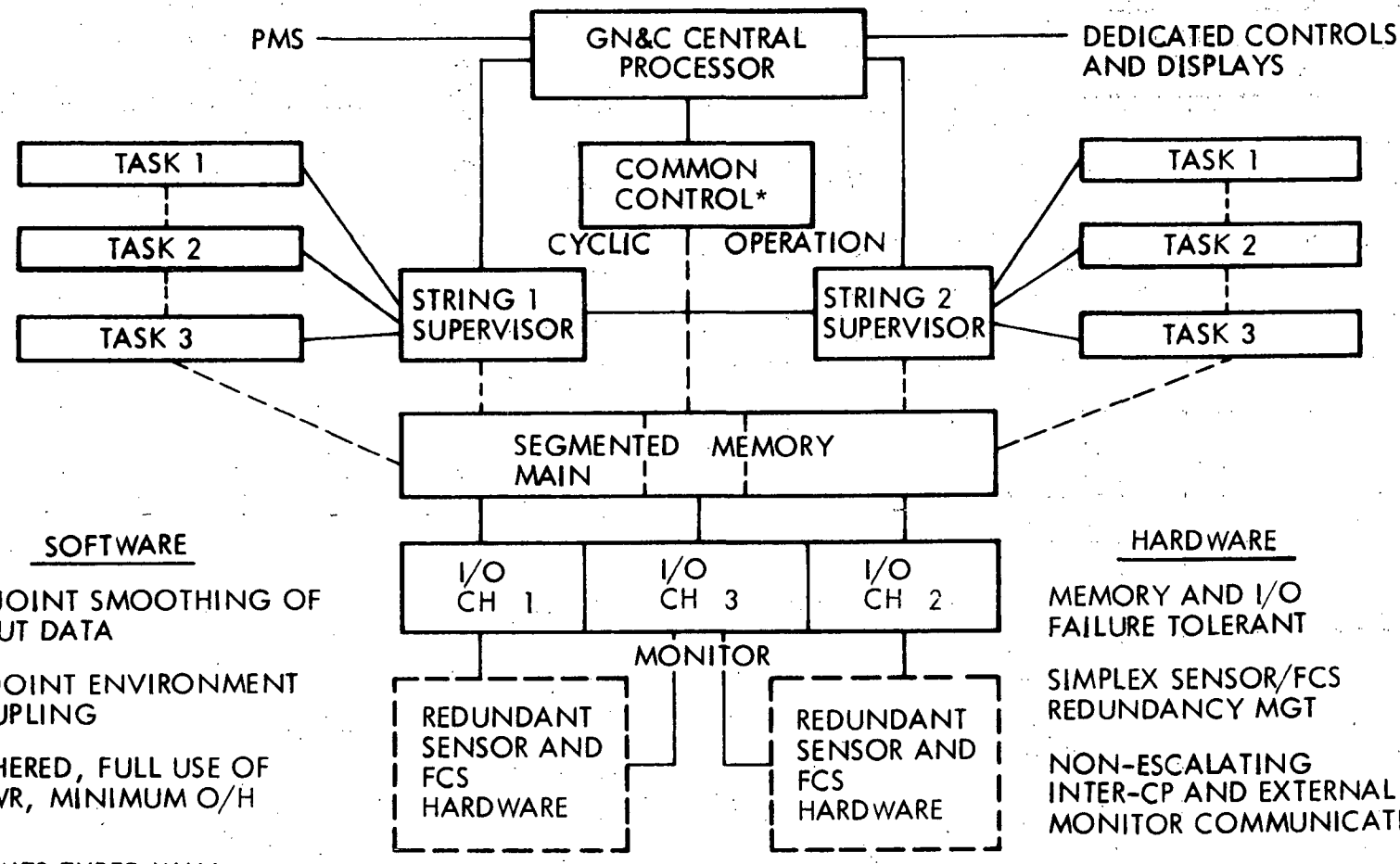
253713

GN&C SOFTWARE RELIABILITY CONSIDERATIONS



SOFTWARE

DISJOINT SMOOTHING OF INPUT DATA

DISJOINT ENVIRONMENT COUPLING

DITHERED, FULL USE OF HDWR, MINIMUM O/H

PERMITS THREE-WAY COMPARISON (PMS BACKUP INCLUDED)

HARDWARE

MEMORY AND I/O FAILURE TOLERANT

SIMPLEX SENSOR/FCS REDUNDANCY MGT

NON-ESCALATING INTER-CP AND EXTERNAL MONITOR COMMUNICATIONS

*MAY NOT BE NECESSARY

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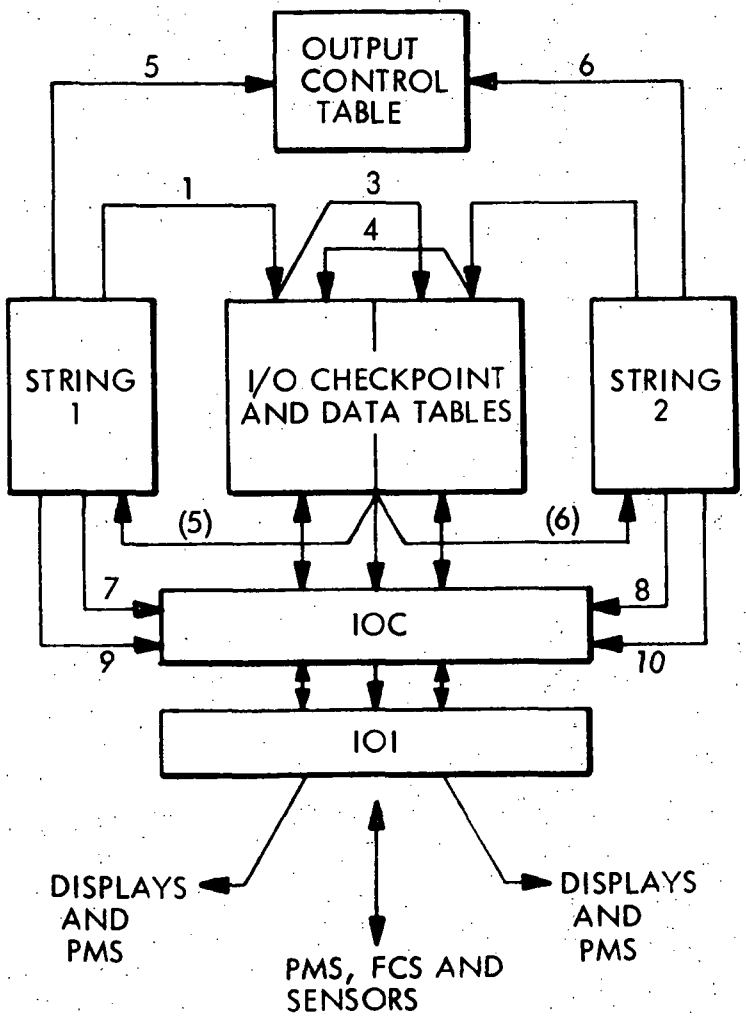
253714

SYNCHRONOUS OPERATION AND SWITCH OVER CONCEPTS

GN&C INTERNAL SOFTWARE REDUNDANCY

SYNCHRONIZATION



SWITCHOVER CONCEPT

OPERATION	STRG 1	YES	NO	STRG 2
CHECK OK?	•	X		•
OUTPUT (INPUT) ?	•	X		•
NEXT CYCLE ?	•	X		•
~	~	X		
CHECK OK ?	•		X	•
ALERT PMS	•			•
OVER LIMIT ?	•		X	•
OUTPUT (INPUT) ?	•	X		•
~	~		X	~
OVER LIMIT ?	•	X		•
ALERT CREW/PMS	•			•
PMS VERIFY ?	•		X	•
OUTPUT (INPUT) ?	•		X	•
~	~	X		~

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253715

GN&C BACKUP CONSIDERATIONS

PMS OPERATION AND SWITCHOVER CONCEPTS

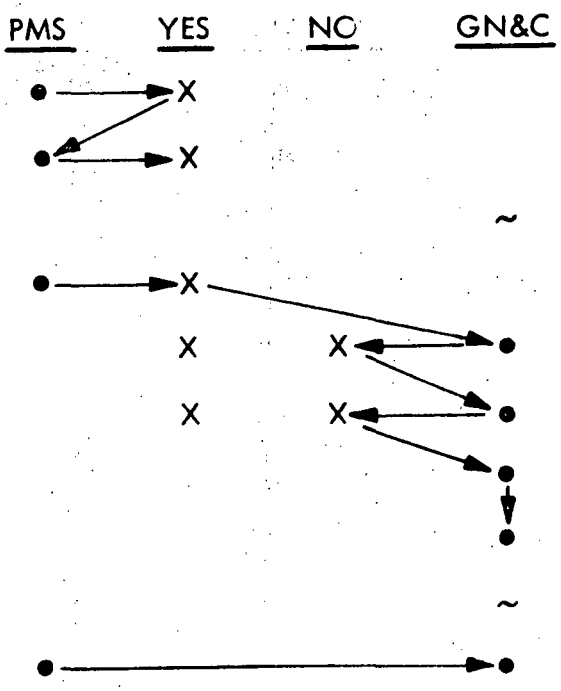
POSSIBLE BACKUP MODES

DYNAMIC PRIORITY (TIME, ALERT, OR CREW ESCALATED) TASK LEVEL SCHEDULING, TOTAL PMS RESOURCES/EXEC

FIXED-HIGHEST PRIORITY, TOTAL PMS RESOURCES/EXEC

MISSION-PHASE-DEDICATED CONFIGURATION; Cp + MEMORY + ±10 + SEPARATE EXEC

SWITCHOVER CONCEPT



SAME AS ABOVE (NUMBER OF STRINGS INCREASED TO 3 OR 4 WITH PMS PORTION DISJOINT)

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253716

REAL-TIME BACKUP SUMMARY

SOFTWARE FUNCTION	IMPLEMENTATION POSSIBILITIES					FAILURE-RECOVERY METHODS	
	GNC COMPUTER	PMS COMPUTER	HARDWIRE	DATA LINK	CREW	SINGLE STRG	GENERIC
ENGINE ORDER COMMANDS	DUAL STRING PRIME	SINGLE STRING BACKUP	ENABLE	AID*	ALTERNATE	SWITCH TO REDUNDANT STRING-ADVISE PMS	SWITCH TO PMS OR MANUAL
STEERING COMMANDS							
POSITION KEEPING							
GNC MODE CONTROL							
TARGETING COMPUTATION				ALTERNATE	AID		
VEHICLE STABILIZATION	PRIME (S/C) AUG (A/C)		PRIME (A/C)	–	ALTERNATE		
STATE VECTOR UPDATE	AUGMENT		ENABLE	PRIME	–	DEGRADED MODE OR GO TO MANUAL AND/OR DATA LINK	NA
SYSTEM PERF MONITOR							
SYSTEMS MANAGEMENT							
SYSTEMS COFIRM							
MAINTENANCE RECORDING							

*MAY BE ALTERNATE FOR EARLY MOF

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253717

GENERIC FAILURE PREVENTION/ BACKUP RECOMMENDATIONS

DISJOINT DESIGN OF GNC SOFTWARE BACKUP IN PMS

EXTENSIVE BITE + STANDARD DIGITAL-SERIAL INTERFACE (S-3A TYPE) FOR REMOTE (PMS/SIU) ON/OFF/MODE CONTROL AS MEANS OF EFFECTIVE SIMULATION/VERIFICATION TESTING IN SIL

ALTERNATE CONTROL PATH CAPABILITY FOR ALL MISSION-CRITICAL SUBSYSTEM CONTROL FUNCTIONS, USING EXISTING HARDWIRE-INDEPENDENT PMS CAPABILITIES

EXTENSIVE OBCOFIRM

- CONTINUOUS, ULTRA-RESPONSIVE FAULT MONITORING
- INTER-MISSION-PHASE, CANNED-PROCEDURE CHECKOUT
- EXEC AND TASK PROGRAM DEGRADED MODES

CREW INTERACTION CONCENTRATED IN PMS

Display and Controls and Crew Interface

ACS Avionics Review

PILOTAGE D&C APPROACH RATIONALE

A. D&C FOR CREW FLIGHT SAFETY

- HARDWIRE
- "SACRED SIX"
- C&W ANNUNCIATORS
- DUPLICATE PILOT/COPILOT LAYOUT
- FLYABLE BY ONE CREWMAN
- NON-COMPUTER DEPENDENT (EXCEPT GN&C)

B. PILOTAGE FLEXIBILITY

- MULTI-PURPOSE VIDEO DISPLAY SYSTEM
- TRANSFER OF CONTROL
- MULTI-FUNCTION KEYBOARD
- CRT AND HARDWIRE DISPLAY MIX UTILIZATION POTENTIAL
- TOTAL A/N, GRAPHIC CRT PRESENTATION CAPABILITY
- SIMPLIFIED USE

PILOTAGE D&C APPROACH RATIONALE (CONT)

C. PERIPHERAL D&C CAPABILITY

- COMPUTER INTERFACE
- CRT-KEYBOARD FLEXIBILITY
- MODULAR INTERFACE AND BUILDUP
- MULTI-FUNCTIONAL UTILIZATION FEATURES

D. INTEGRATION FEATURES

- MAJORITY OF OFF-SHELF EQUIP. (S-3A, L-1011, C-5A)
- MODULARITY
- BUILT-IN TEST CAPABILITY
- DEMONSTRABLE MAINTENANCE
- PROVEN USE HISTORIES

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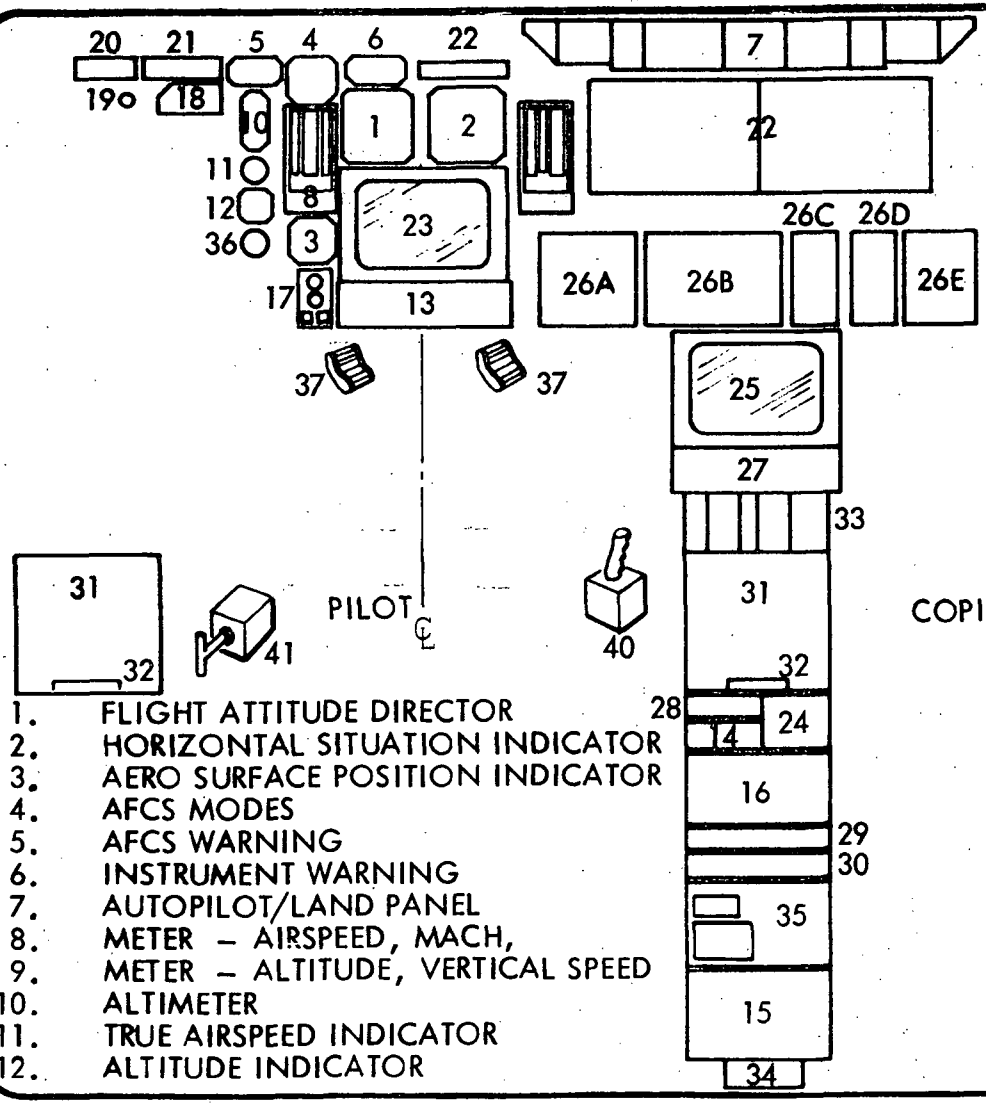
MAIN PILOT/COPILOT INSTRUMENT PANEL



1. FLIGHT ATTITUDE DIRECTOR
2. HORIZONTAL SITUATION INDICATOR
3. AERO SURFACE POSITION INDICATOR
4. AFCS MODES
5. AFCS WARNING
6. INSTRUMENT WARNING
7. AUTOPILOT/LAND PANEL
8. METER – AIRSPEED, MACH,
9. METER – ALTITUDE, VERTICAL SPEED
10. ALTIMETER
11. TRUE AIRSPEED INDICATOR
12. ALTITUDE INDICATOR
13. MULTI-FUNCTION KEYBOARD
14. MAIN ENGINE OVERRIDE CONTROLS
15. RCS ISOLATION PANEL
16. OMS ENGINE/GIMBAL CONTROLS
17. TANK JETTISON OVERRIDE
18. ABORT
19. INSTR BRIGHTNESS CONTROLS
20. C&W TEST PANEL
21. BOOSTER STATUS PANEL
22. MASTER C&W
23. MULTI-FUNCTION DISPLAY UNIT
24. ABES ENGINE START
25. MULTI-FUNCTION DISPLAY UNIT

26A PROPULSION DISPLAY – OMS
26B PROPULSION DISPLAY – RCS
26C PROPULSION DISPLAY – ABES
26D PROPULSION DISPLAY – APU
26E PROPULSION DISPLAY – MAIN

27. MULTI-FUNCTION KEYBOARD (S/S & GN&C)
28. DRAG CHUTE, SENSOR, AND ANTENNA
29. PMS POWER
30. GN&C POWER
31. THROTTLES, SPEED BRK, TRIM CONTROLS
32. ABES DEPLOY
33. GN&C MODE SELECT
34. LANDING GEAR CONTROLS
35. COMMUNICATION PANEL
36. G-METER
37. RUDDER/BRAKE PEDALS

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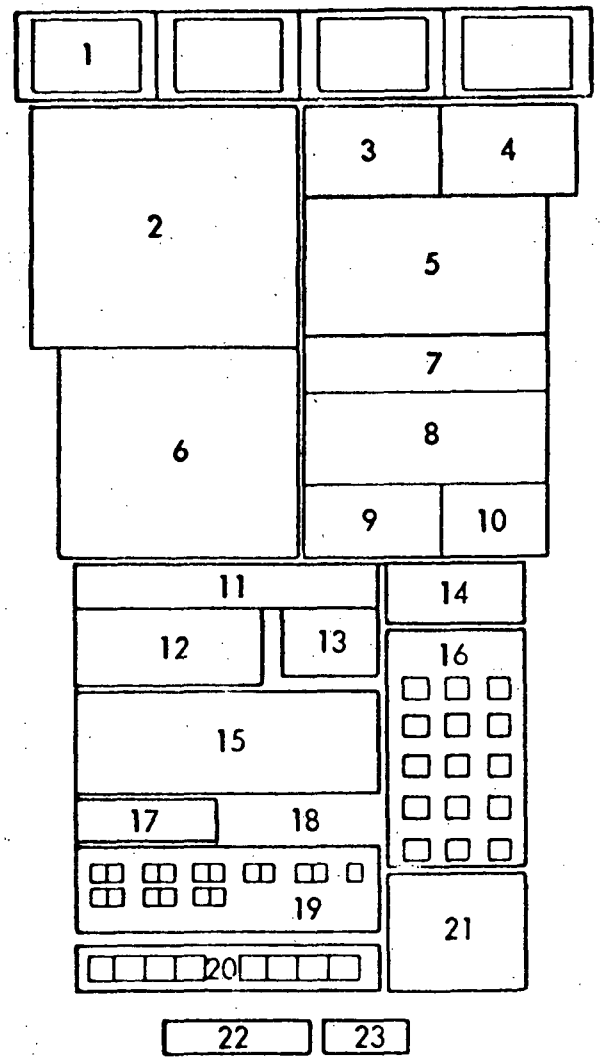
253802

OVERHEAD INSTRUMENT PANEL



1. ENGINE FIRE CONTROL PANELS
2. AC GENERATOR PANEL
3. INVERTER CONTROL
4. INVERTER STATUS
5. TRANSFORMER/RECTIFIER PANEL
6. FUEL CELLS/BATTERIES PANEL
7. CRYOGENS PANEL
8. FUEL CELL TO DC BUS PANEL
9. FUEL CELL READY STATUS
10. PURGE CONTROL
11. WINDOW/CONDITIONING CONTROLS
12. EXTERIOR LIGHTS PANEL
13. INTERIOR LIGHTS PANEL
14. ANTI-SKID CONTROLS
15. ECS PANEL
16. APU PANEL
17. AIR DATA SENSOR HEAT
18. GROWTH AREA
19. FCS COMPUTER STATUS
20. RUDDER/ELEVON LIMITERS
21. APU ENGINE START
22. MISSION TIME
23. EVENT TIME

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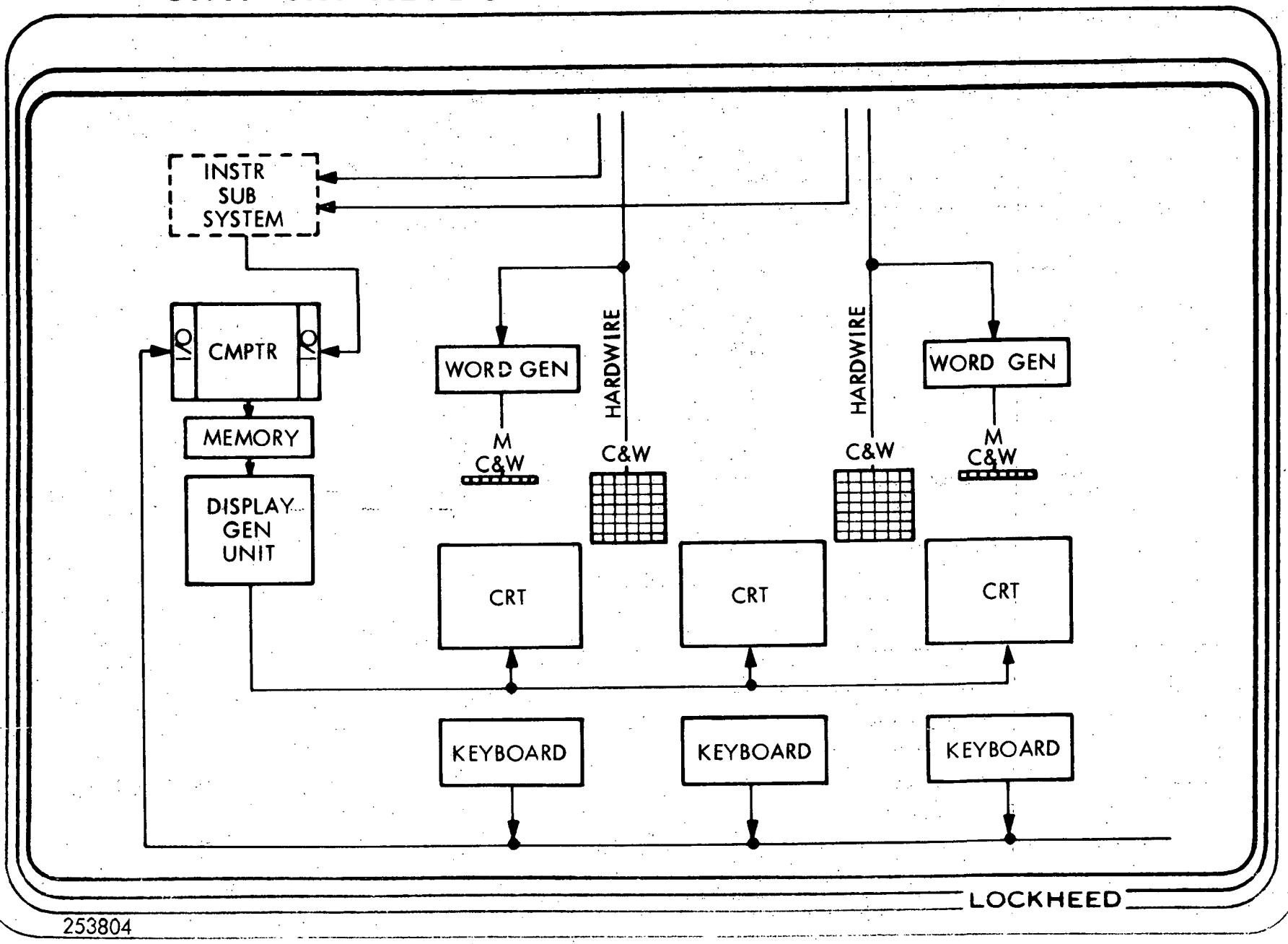
C&W-CRT-KEYBOARD-COMPUTER INTERFACE



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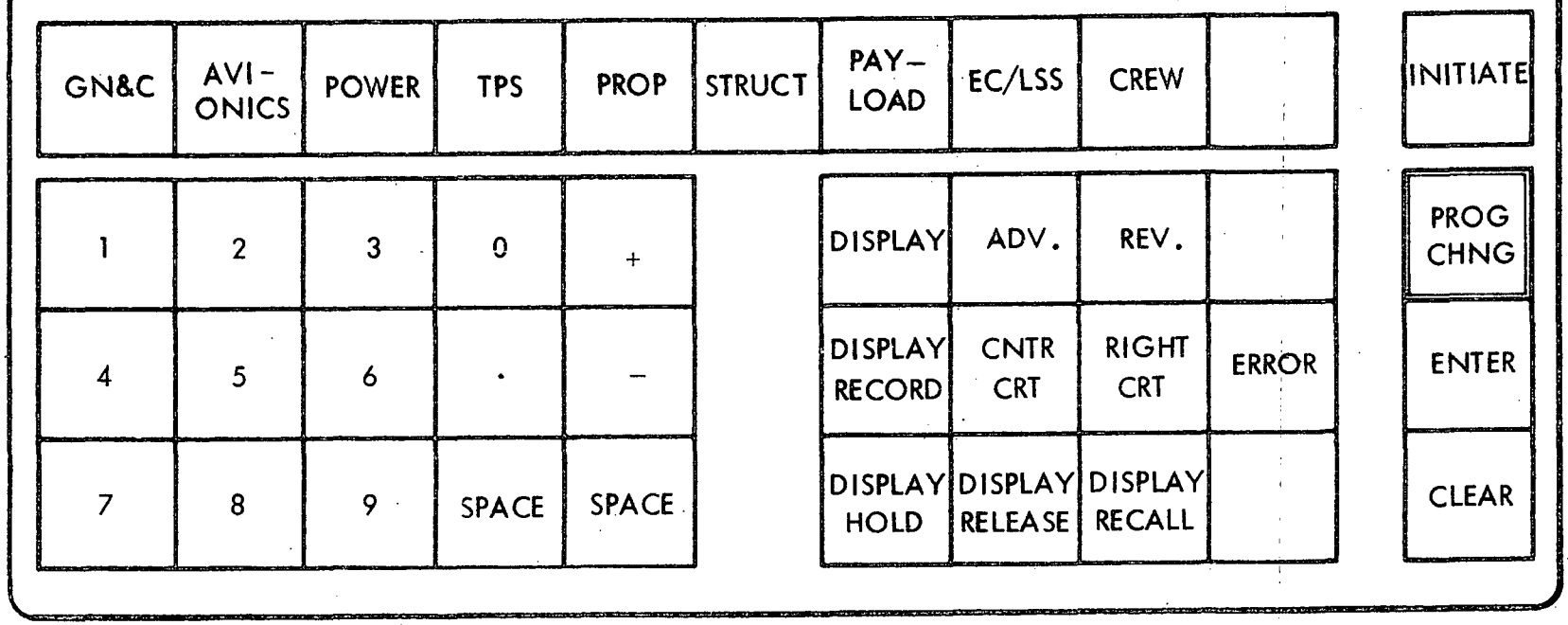
PILOTAGE CREW KEYBOARD LAYOUT

PILOT KEYBOARD



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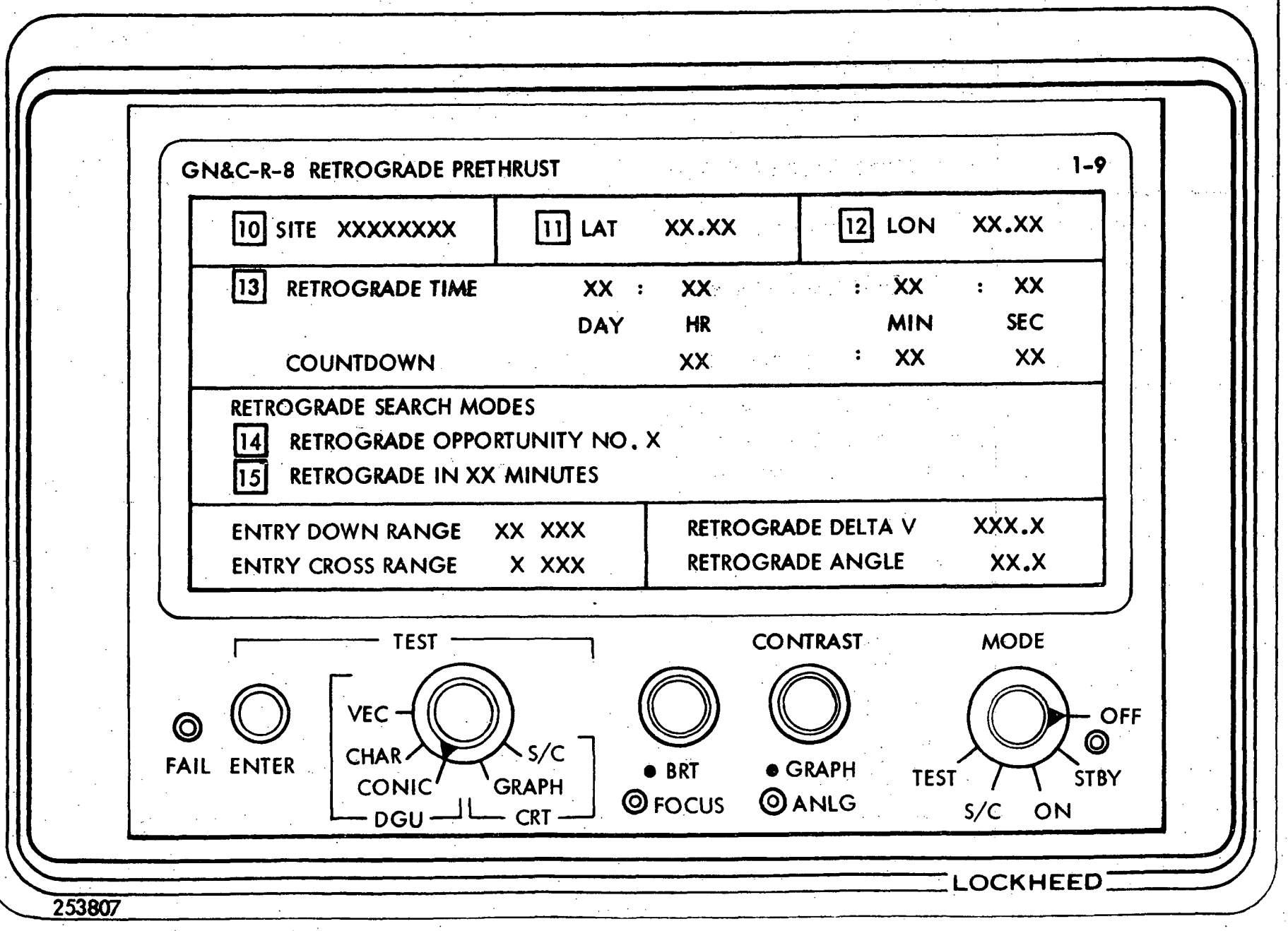
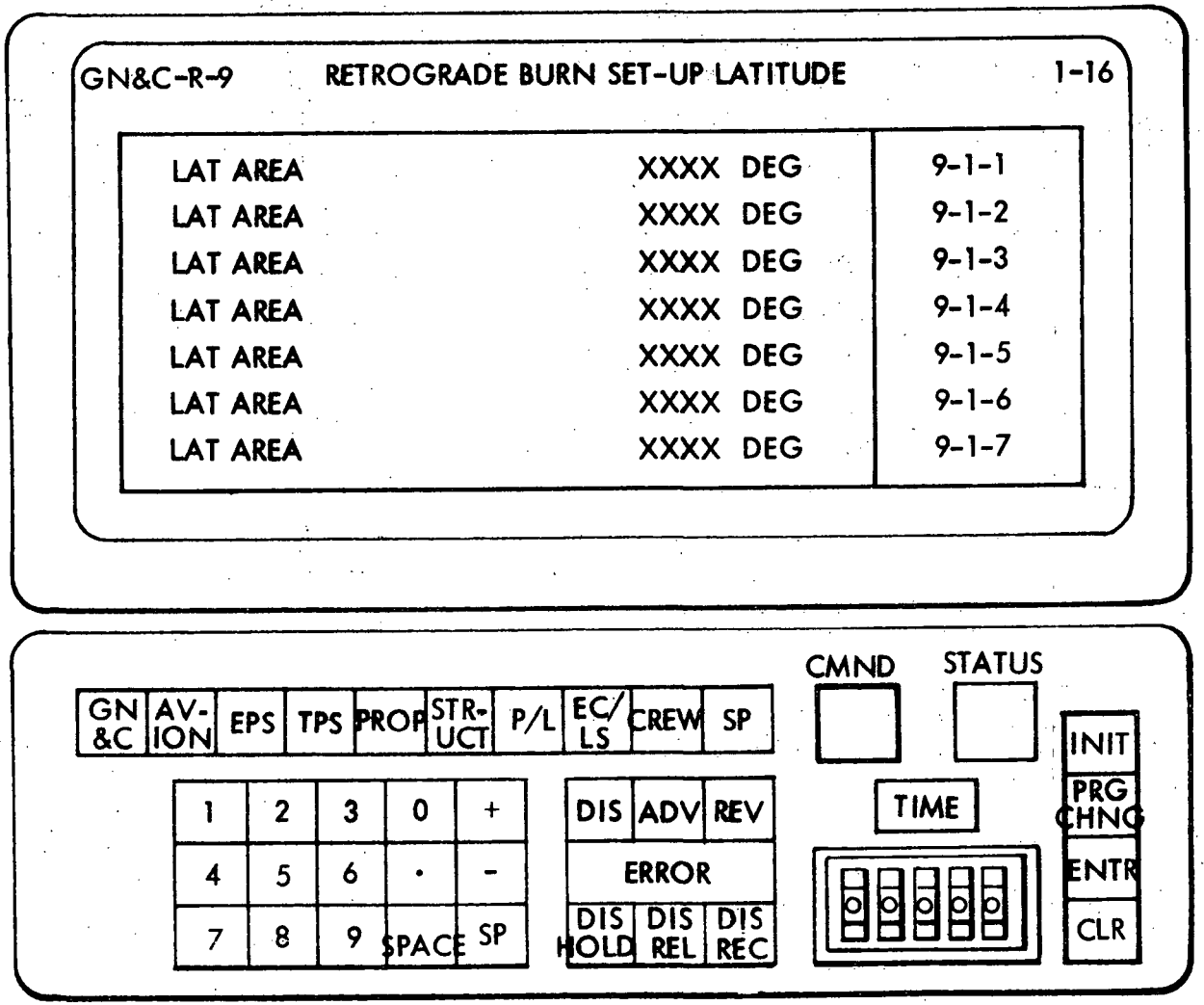
253805

TYPICAL GN&C MDU PRESENTATION



MULTIFUNCTION DISPLAY UNIT AND KEYBOARD CENTER POSITION



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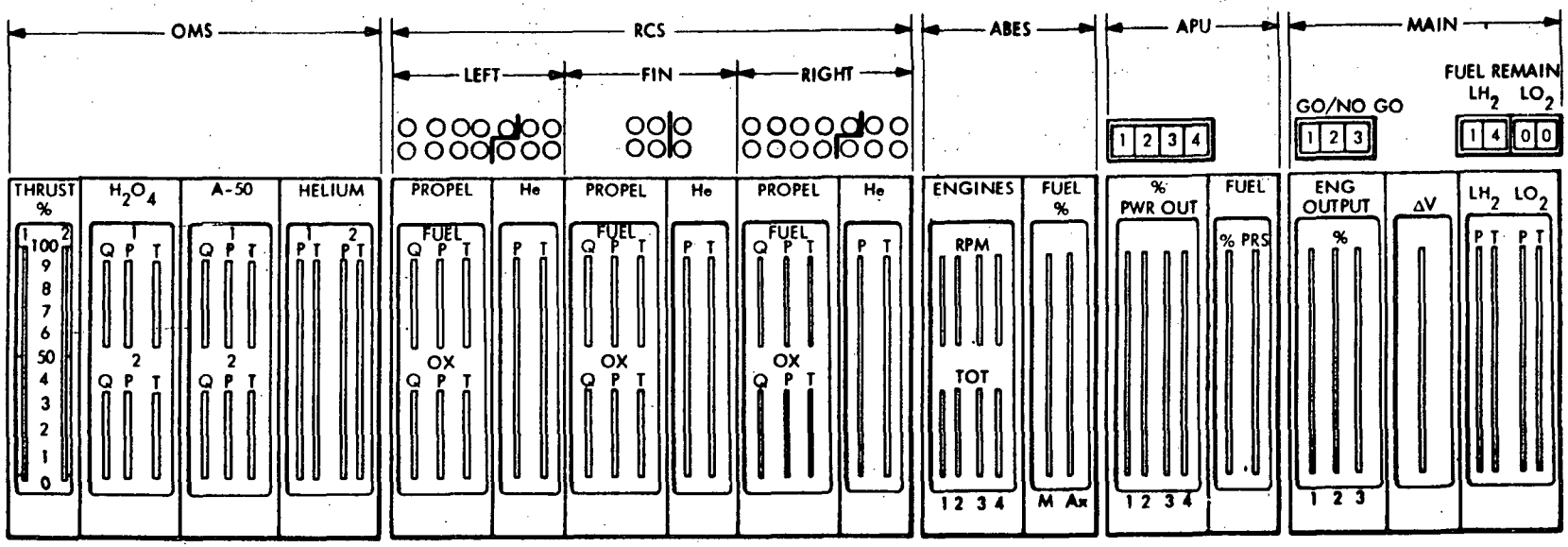
253806

PROPULSION PANEL



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253810

PROPULSION SYSTEM DISPLAY PARAMETERS

SYST	DISPLAY NO.	METERS	PARAMETER	PERFORMANCE
ABES	4	1	ENGINES (4)	RPM – 0–100% OF CAPABILITY
	4		ENGINES (4)	TOT – TURBINE OUTPUT TEMPERATURE
	1	1	TANK(S) (1)	% FUEL REMAINING 0–100%
	1		TANK(S) FERRY (1)	% FUEL REMAINING 0–100%
APU	4	1	ENGINES (4)	% OF POWER OUTPUT
	4	4	ENGINES (4)	LIGHTS INDICATE OPERATING UNITS
	1	1	TANK (1)	% FUEL REMAINING 0–100%
	1		TANK (1)	FUEL TANK FEED PRESSURE
MAIN	3	1	ENGINES (3)	% OF POWER OUTPUT CAPABILITY
	3	3	ENGINES (3)	LIGHTS INDICATE ENGINE FAILURE
	1	1	ENGINE (1)	ΔV REMAINING
	2	1	TANKS (2)	LH_2 AND LO_2 TEMPERATURE
	2		TANKS (2)	LH_2 AND LO_2 PRESSURE
	4	4	TANKS (4)	LH_2 AND LO_2 LIQUID LEVEL REMAINING

LOCKHEED

253830

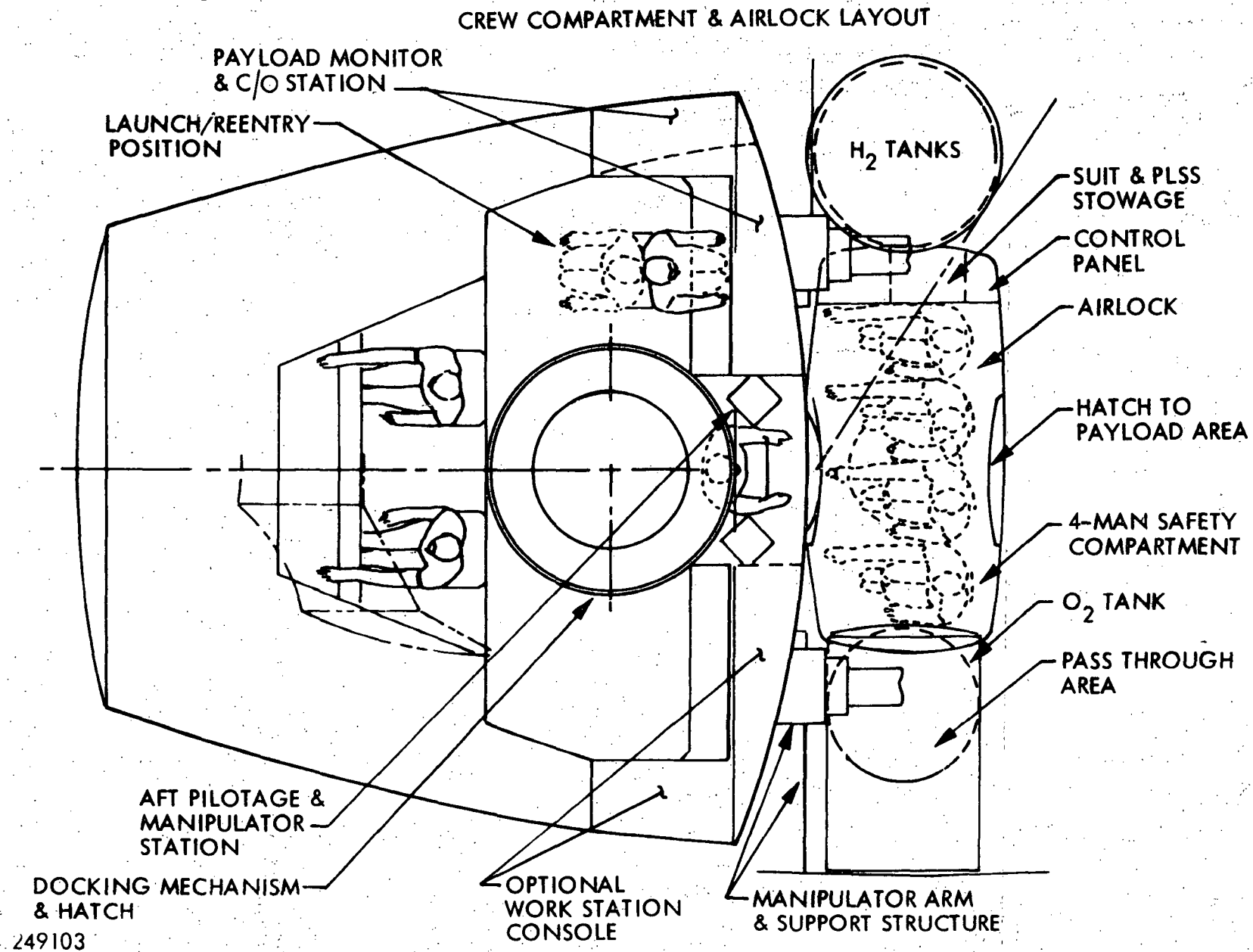
PROPULSION SYSTEM DISPLAY PARAMETERS (CONT)

SYST	DISPLAY NO.	METERS	PARAMETERS	PERFORMANCE
OMS	2	1	ENGINES (2)	% OF POWER OUTPUT CAPABILITY
	2		TANKS (2)	N_2O_4 - QUANTITY
	2	1	TANKS (2)	PRESSURE
	2		TANKS (2)	TEMPERATURE
	2		TANKS (2)	FUEL (A-50) - QUANTITY
	2	1	TANKS (2)	PRESSURE
	2		TANKS (2)	TEMPERATURE
	2	1	TANK (2)	HELIUM - PRESSURE
	2		TANK (2)	TEMPERATURE
RCS	3		TANKS (3)	PROPELLANT - QUANTITY
	3		TANKS (3)	PRESSURE
	3	3	TANKS (3)	TEMPERATURE
	3		TANKS (3)	OX - QUANTITY
	3		TANKS (3)	PRESSURE
	3		TANKS (3)	TEMPERATURE
	3	3	TANKS (3)	HELIUM - PRESSURE
	3		TANKS (3)	TEMPERATURE
	34	34	ENGINES (34)	LIGHTS INDICATE NON-OPERATING ENGINES
TOTAL	66	17	METERS	
		21	INDICATOR LIGHTS	
		4	DIGITAL READOUTS	

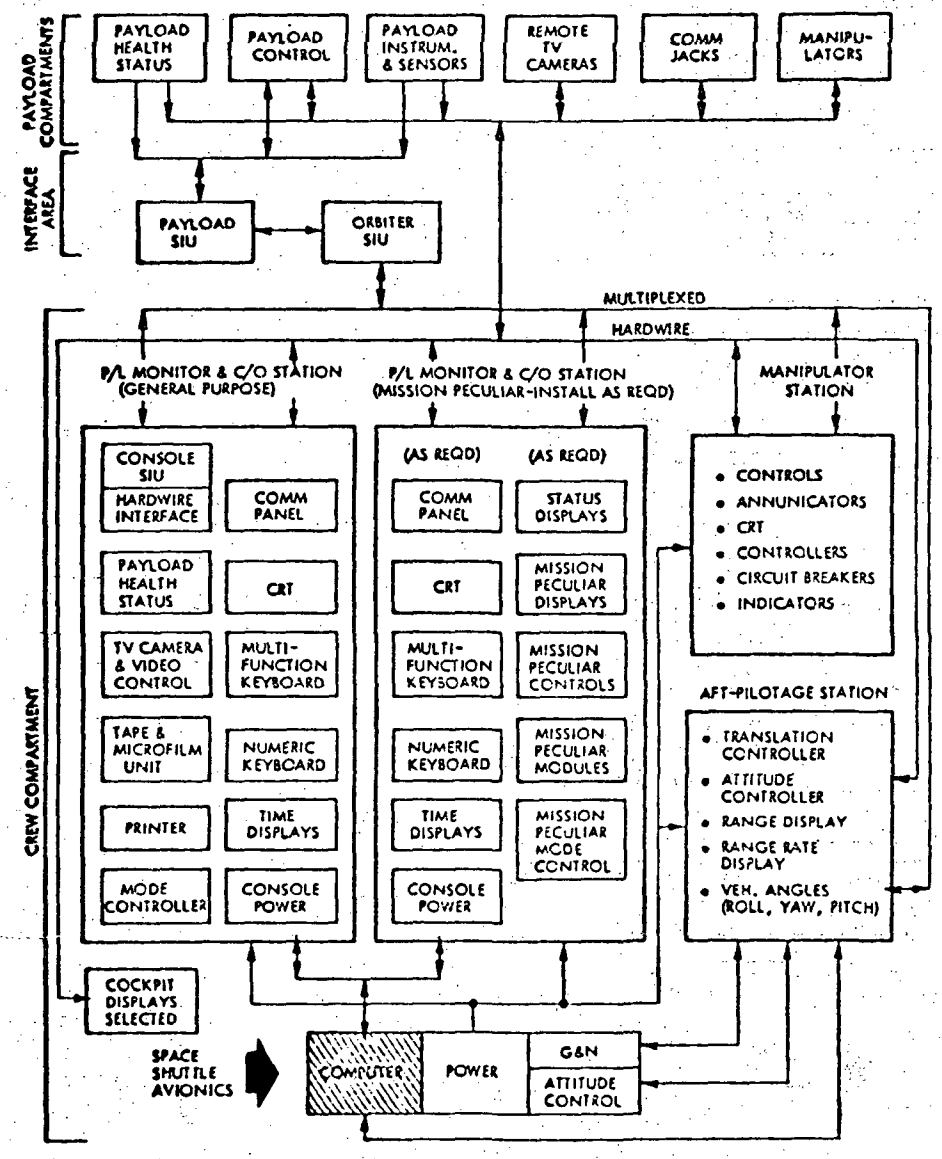
LOCKHEED

253830A

CREW COMPARTMENT AND AIRLOCK LAYOUT

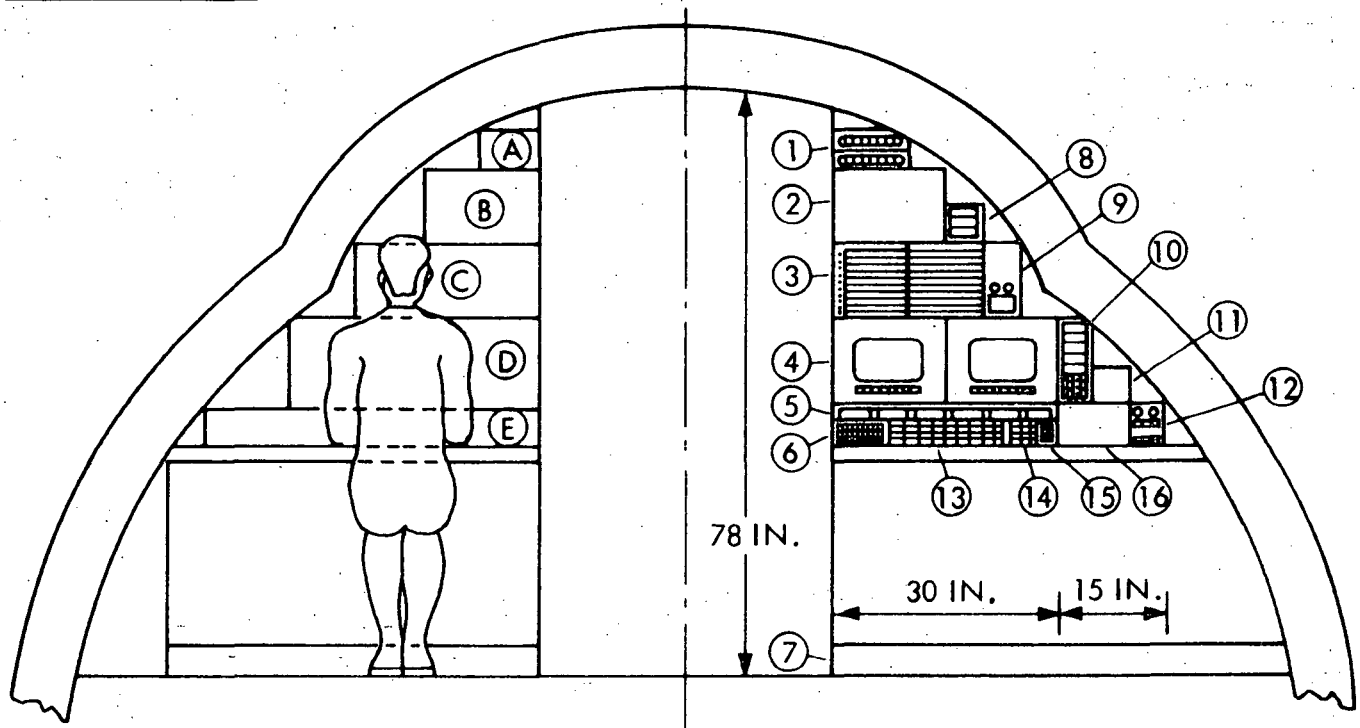


PAYLOAD CONTROL/DISPLAY INTERFACE



233404

PAYLOAD CONSOLES – GENERAL PURPOSE AND MISSION PECULIAR



PAYLOAD CONSOLE
– MISSION PECULIAR MODULES

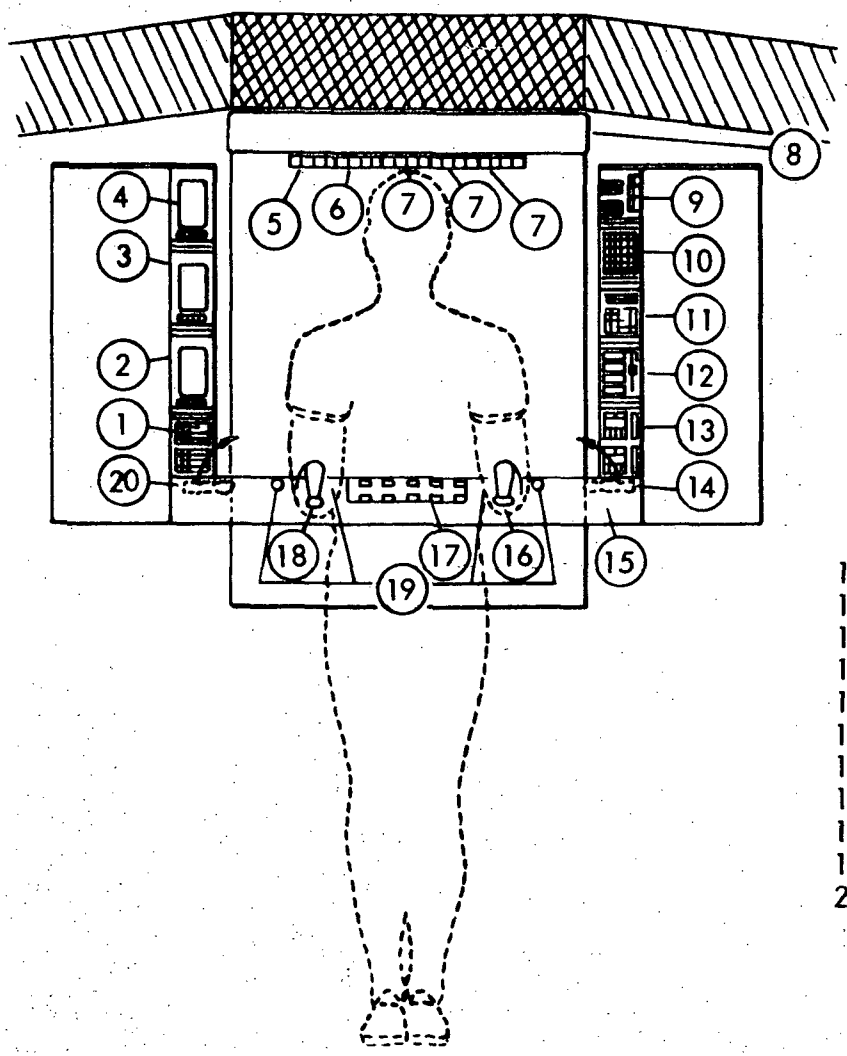
PAYLOAD MONITORING & C/O CONSOLE
– GENERAL PURPOSE

A. MODULE 5H x 8W x 20D
B. MODULE 10H x 15W x 20D
C. MODULE 10H x 25W x 20D
D. MODULE 10H x 35W x 20D
E. MODULE 10H x 45W x 20D

1. MISSION & EVENT TIMERS
2. GROWTH/MISSION PECULIAR
3. MALFUNCTION ANNUNCIATOR & STATUS DESCRIPTORS
4. MULTI-FUNCTION DISPLAY UNIT (CRT) - 2
5. REMOTE TV CAMERA CONTROLS & VIDEO TAPE CONTROLS
6. MODE CONTROLLER
7. KICK SPACE
8. ABORT DISPLAY
9. TAPE/FILM UNIT
10. PAYLOAD SIU CONTROLS
11. GROWTH/MISSION PECULIAR
12. PRINTER
13. MULTI-FUNCTION KEYBOARD
14. NUMERIC INPUT CONTROL
15. POWER CONTROLS
16. GROWTH/MISSION PECULIAR

DO6570
/33439

MANIPULATOR / PILOTAGE STATION — AFT



1. TELEOPERATOR C/D PANEL
2. TV MONITOR SCREEN
3. TV MONITOR SCREEN
4. TV MONITOR SCREEN
5. RANGE DISPLAY
6. RANGE RATE DISPLAY
7. VEHICLE ANGLES
8. AFT VIEWING MECHANISM
9. PAYLOAD DOCKING SENSOR PANEL
10. UMBILICAL INTERFACE PANEL
11. PAYLOAD/CRADLE CAPTIVE MECH PANEL
12. DEPLOY/RETRIEVE MECH BOOM PANEL
13. MANIPULATOR C/D PANEL
14. ATTITUDE CONTROLLER
15. WORK SHELF PANEL
16. MANIPULATOR CONTROL
17. MODE SELECT & TV SLEW CONTROL PANEL
18. MANIPULATOR CONTROL
19. TELEOPERATOR CONTROLLERS
20. TRANSLATION CONTROLLER

DO6569
233442

ATMOSPHERIC SCIENCE AND TECHNOLOGY

H-R IR RADIOMETER DETECTION MODULE (CLOUD COVER-TEMP)

UV SPECTROMETER
NEAR IR SPECTROMETER
} EARTH SPECTRAL RADIANCE

MICROWAVE SPECTROMETER – (EARTH/ATMOSPHERE SPECTRAL RADIANCE)

STAR TRACKER TELESCOPE – (ATMOSPHERE VERTICAL PRESSURE DISTRIBUTION)

MULTI-CHANNEL RADIOMETERS (HEAT BUDGET OF HURRICANES, TORNADOES, STORMS)

LOCKHEED

253815

ASTRONOMY/ASTROPHYSICS

- TELESCOPE OPERATIONS MODULE
- CORONAGRAPH MODULE
- RADIO ASTRONOMY 1 TO 5 MCPS RANGE MODULE
- RADIO ASTRONOMY 1 TO 5 MCPS USING "V" ANTENNA
- MICROWAVE SPECTROPHOTOMETER MODULE
- X-RAY DETECTOR
- EMISSION LINE RADIOMETRY
- ULTRAVIOLET AND X-RAY PHOTOMETRICS MODULE
- DIPOLE AND V-ANTENNA ARRAY DEPLOYMENT/RETRACT UNIT
- IR EMISSION LINE RADIOMETRY SYSTEM

LOCKHEED

253819

OCEANOGRAPHY/MARINE TECHNOLOGY

RADAR IMAGING (0.3 - 2.0 GC) UNIT
MICROWAVE RADIOMETRY (4, 8.5, 15, 33 MM) MODULE
PULSED VHF REFLECTIVITY (75 to 450 MC) UNIT

OPTICAL (GLITTER OBSERVATION) TELESCOPE UNIT
RADAR (BACK SCATTER) UNIT
IR AND MICROWAVE RADIOMETRY (0.1U)

MULTISPECTRAL SENSOR (1 - 30U)
HIGH RESOLUTION PHOTOGRAPHY

RADAR (BACK SCATTER) UNIT
RADIOMETRIC (TEMPERATURE AND HEAT FLUX) UNIT

IR RADIOMETRY (2 - 15U)
MULTISPECTRAL PHOTOGRAPHY

SEA ICE SPECTRAL SIGNATURES – ICE MASSES/BERGS AND THICKNESS

WAVES AND CURRENTS SPECTRAL SIGNATURES – WIND, WAVE, SWELL HEIGHT, AND CURRENT MEANDERINGS

COASTAL AND MARINE GEOLOGY SPECTRAL SIGNATURES – BEACH/COASTAL STRUCTURES, SEDIMENTATION

MARINE METEOROLOGY AND OCEANOGRAPHIC FORECASTING SPECTRAL SIGNATURES – AIR/SEA INTERACTION AND ENERGY EXCHANGE

MARINE BIOLOGY SPECTRAL SIGNATURES – MIGRATION, SCHOOLING, AND DISTRIBUTION

GEOLOGY-HYDROLOGY

PASSIVE MULTISPECTRAL IMAGERY (0.3 - 30U) HIGH RESOLUTION PHOTOGRAPHY (0.4 - 9U) RADAR IMAGERY (35 KMC)	GEOLOGICAL FIELD MAPPING KEY SPECTRAL SIGNATURES
VISUAL PHOTOGRAPHY (.4 - 9U) HIGH RESOLUTION MICROWAVE EMISSION IMAGINING (9 KMC) IR SPECTROMETERS (1.0 - 30U)	ECONOMIC GEOLOGY KEY SPECTRAL SIGNATURES
HIGH RESOLUTION (VISUAL RANGE) PHOTOGRAPHY INFRARED IMAGER (2 - 15U) INFRARED SPECTROMETER (1.0 - 3U) MICROWAVE IMAGER (9 KMC) MICROWAVE RADIOMETER (4, 8.5, 15, 33 MM) NONCOHERENT IMAGING RADAR (35 KMC)	HYDROLOGIC PHENOMENA KEY SPECTRAL SIGNATURES
VISUAL PHOTOGRAPHY (0.4 - 9U) MULTISPECTRAL PHOTOGRAPHY (0.2 - 1U) RADAR IMAGERY (0.3 - 2 GC) MAGNOMONOMETER	GEOMOPHOLOGY AND TECTONOPHYSICS SENSOR FORMS – LAND FORMS, EROSION AND ISOSTASY
ACTIVE VHF RADAR (75 - 450 MC) HIGH RESOLUTION MICROWAVE RADAR (0.3 - 2 GC) (SIDE LOOKING COHERENT POLARIZATION RADAR) HIGH RESOLUTION MICROWAVE EMISSION IMAGING (9 KMC)	PETROLOGY AND MINERALOGY SPECTRAL SIGNATURES – ROCK COMPOSITION/VARIATION

LOCKHEED

253818

PHYSICAL SCIENCES

- RADIATION MONITOR UNIT
- AIRGLOW HORIZON PHOTOGRAPHY UNIT
- MAGNOMONOMETER (FIELD LINES)
- PARTICULATE ANALYZER
- ENVIRONMENT ANALYSIS UNIT
- THERMOANALYZER

LOCKHEED

253819A

GEOGRAPHY

VISUAL PHOTOGRAPHY-CARTOGRAPHIC CAMERA (75 x 75 NM FIELD, 20-FT RESOLUTION) (0.7U)

MAPPING CAMERAS (300 x 300 NM FIELD, 200-FT RESOLUTION) (0.4 - 0.5 - 0.9U)

CARTOGRAPHIC AND GEODETIC SURVEY SPECTRAL SIGNATURES – TOPOGRAPHIC FEATURES

MULTISPECTRAL IMAGERY UNIT (0.2 - 1U)

MULTIFREQUENCY, MULTIPOLARIZATION, COHERENT RADAR SYSTEM (8GC, 2GC, 5GC)

IR IMAGES (2 - 15U)

URBAN GEOGRAPHY SPECTRAL SIGNATURES – CULTURAL FEATURES

MULTISPECTRAL PHOTOGRAPHY (0.4 - 0.9U)

HIGH-FREQUENCY SIDE-LOOKING RADAR (35 KMC)

HIGH-RESOLUTION, COHERENT, SIDE-LOOKING RADAR (8 KMC)

TRANSPORTATION GEOGRAPHY SPECTRAL SIGNATURES

VISUAL PHOTOGRAPHY (0.7U)

MULTISPECTRAL PHOTOGRAPHY

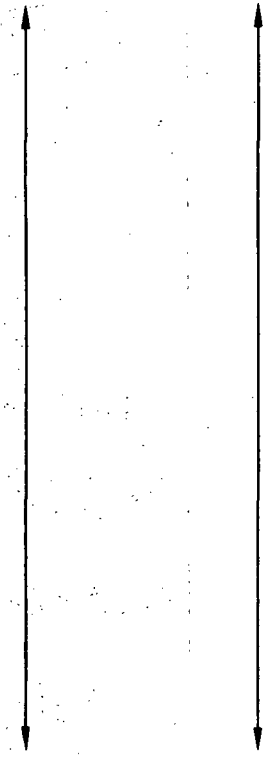
IR IMAGES (2 - 15U)

MULTIFREQUENCY RADAR (8GC, 2GC, 0.5GC)

POPULATION DISTRIBUTION SPECTRAL SIGNATURES – SETTLEMENT, LAND USE, AND DIFFUSION

AGRICULTURE/FORESTRY

- PASSIVE MULTI-SPECTRAL IMAGER AND SENSOR – (VEGETATION SIGNATURES) [VISUAL TO MICROWAVE]
- IR IMAGER
- MICROWAVE IMAGER
- MICROWAVE RADIOMETER
- VHF PULSE REFLECTIVITY UNIT
- EARTH MAPPING CAMERA UNIT
- NONCOHERENT IMAGING RADAR
- COHERENT IMAGING RADAR
- PANORAMIC CAMERA



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253815A

COMMUNICATIONS AND NAVIGATION / TRAFFIC CONTROL AREA

WIDEBAND TUNABLE RECEIVERS (FREQUENCY, RADIATION, AND INTERFERENCE)

RF DETECTORS AND RECORDERS

ANTENNA DEPLOYMENT/RETRACTION UNIT

TRANSMITTERS – WIDE BAND

INTERFEROMETER CONTROL UNIT

OPTICAL SPECTROMETER

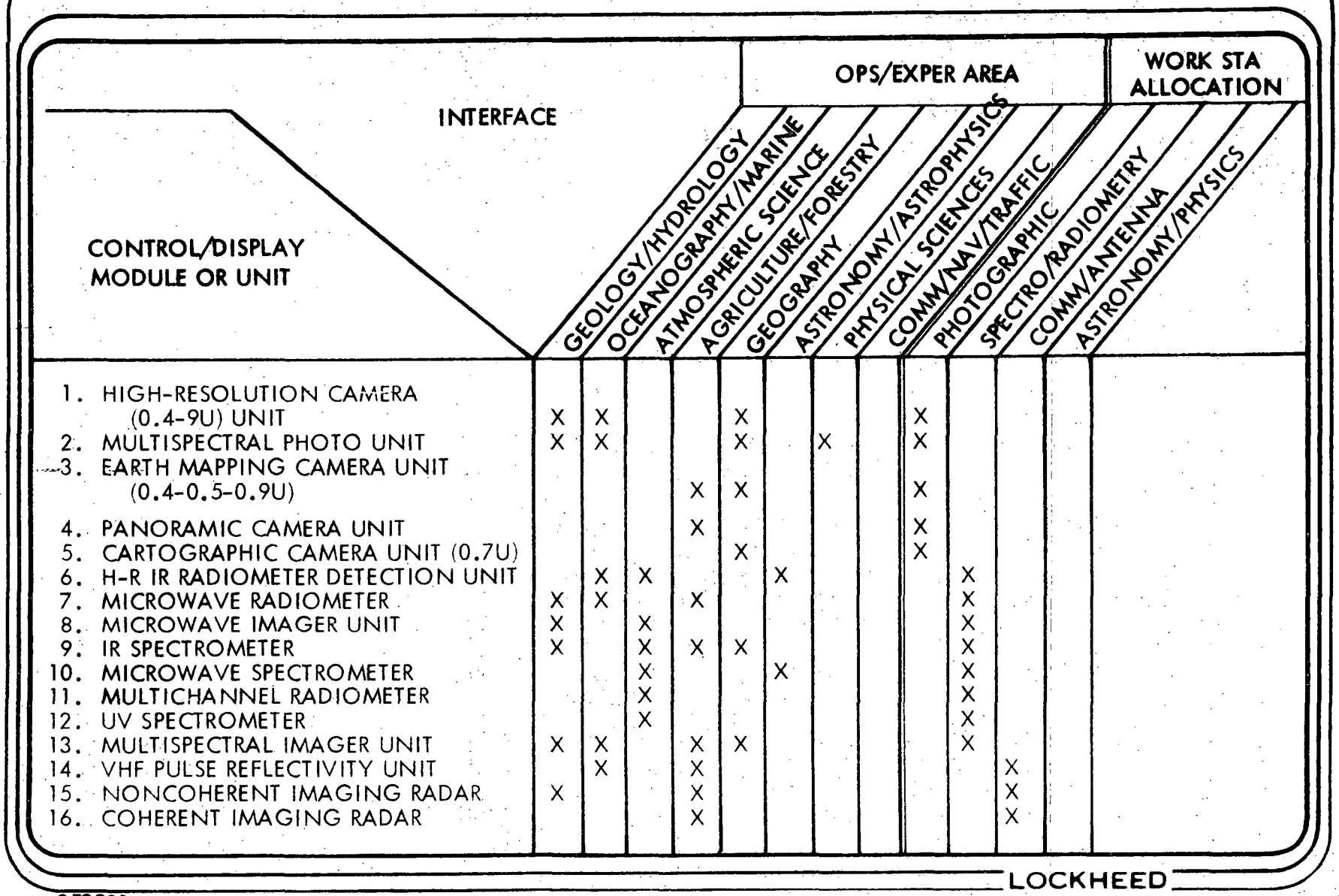
LASER UNIT

PROPOGATION MEDIUM SIGNATURES – ATMOSPHERE, SCATTER, SIGNAL TRANSMISSIBILITY

LOCKHEED

253816

OPS/EXPER C/D MODULE REQTS AND ALLOCATION

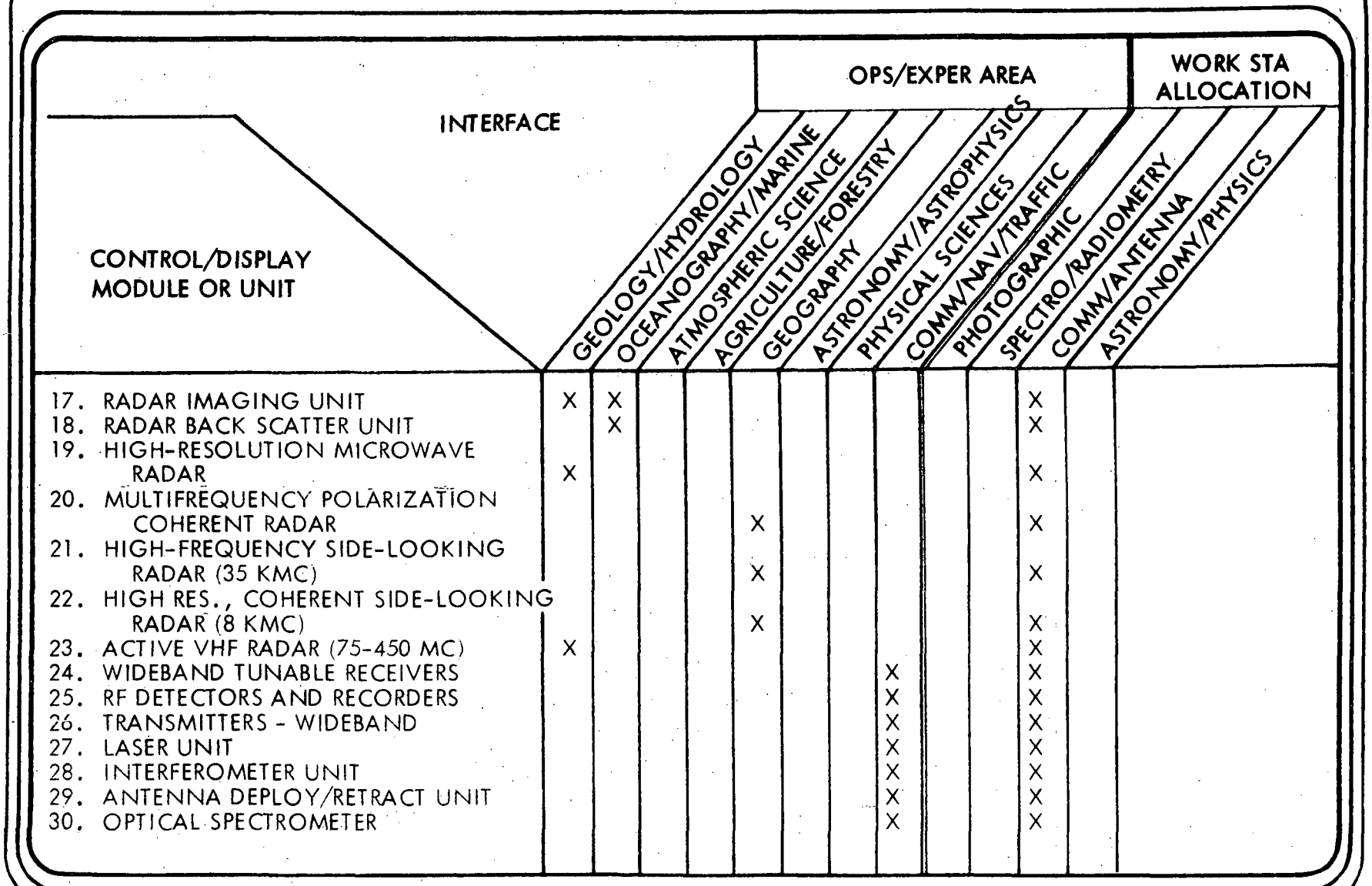


CONTROL/DISPLAY MODULE OR UNIT (INTERFACE)	GEOLOGY/HYDROLOGY	OCEANOGRAPHY/MARINE	ATMOSPHERIC SCIENCE	AGRICULTURE/FORESTRY	GEOGRAPHY	ASTRONOMY/ASTROPHYSICS	PHYSICAL SCIENCES	COMM/NAV/TRAFFIC	PHOTOGRAPHIC	SPECTRO/RADIOMETRY	COMM/ANTENNA	ASTRONOMY/PHYSICS
	OPS/EXPER AREA											WORK STA ALLOCATION
1. HIGH-RESOLUTION CAMERA (0.4-9U) UNIT	X	X			X				X			
2. MULTISPECTRAL PHOTO UNIT	X	X			X		X		X			
3. EARTH MAPPING CAMERA UNIT (0.4-0.5-0.9U)				X	X				X			
4. PANORAMIC CAMERA UNIT				X					X			
5. CARTOGRAPHIC CAMERA UNIT (0.7U)					X				X			
6. H-R IR RADIOMETER DETECTION UNIT		X	X			X				X		
7. MICROWAVE RADIOMETER	X	X		X						X		
8. MICROWAVE IMAGER UNIT	X		X							X		
9. IR SPECTROMETER	X		X	X	X					X		
10. MICROWAVE SPECTROMETER			X			X				X		
11. MULTICHANNEL RADIOMETER			X							X		
12. UV SPECTROMETER			X							X		
13. MULTISPECTRAL IMAGER UNIT	X	X		X	X					X		
14. VHF PULSE REFLECTIVITY UNIT		X		X							X	
15. NONCOHERENT IMAGING RADAR	X			X							X	
16. COHERENT IMAGING RADAR				X							X	

LOCKHEED

253821

OPS/EXPER C/D MODULE REQTS AND ALLOCATION (CONT)

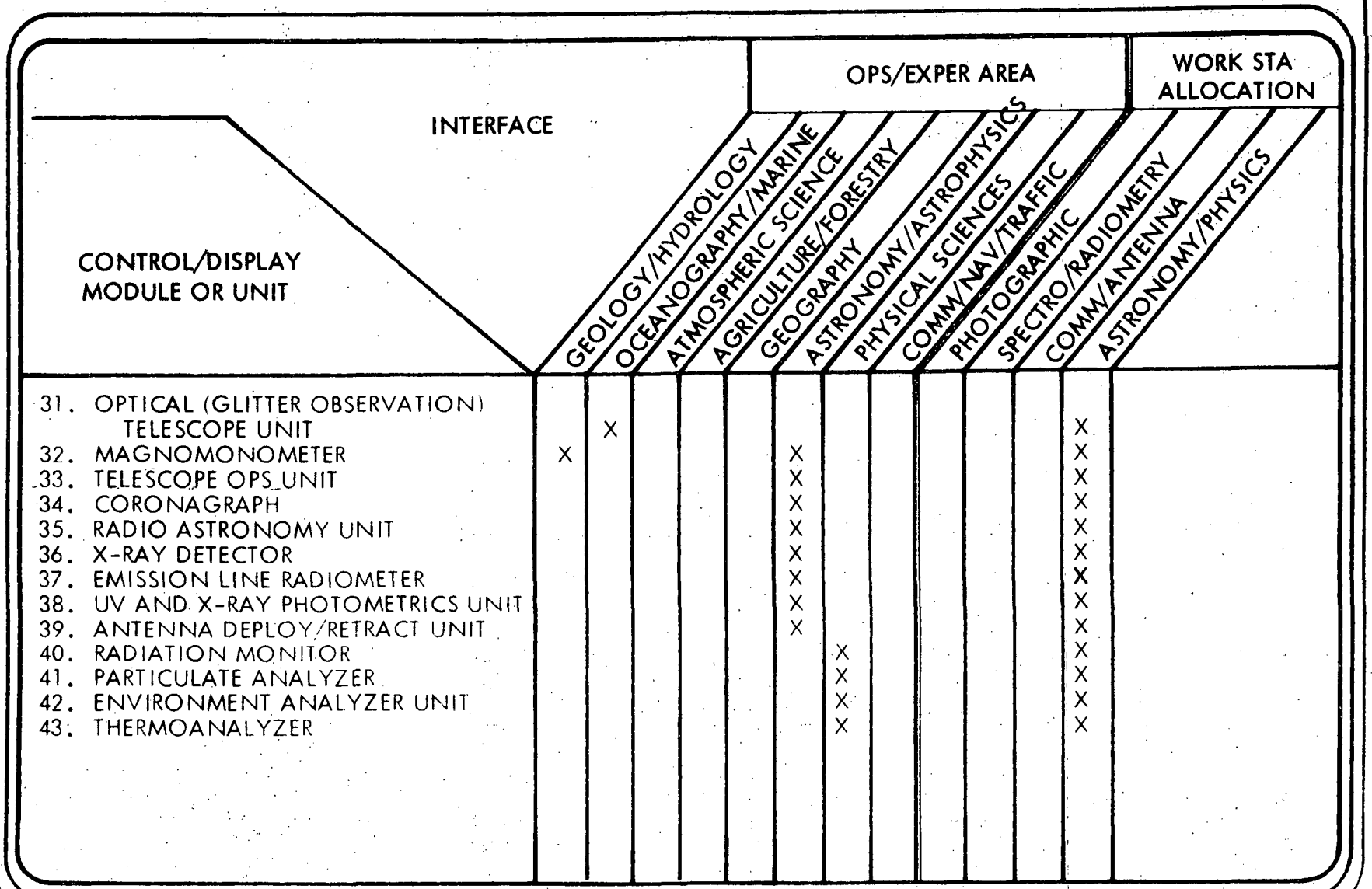


CONTROL/DISPLAY MODULE OR UNIT (INTERFACE)	GEOLOGY/HYDROLOGY	OCEANOGRAPHY/MARINE	ATMOSPHERIC SCIENCE	AGRICULTURE/FORESTRY	GEOGRAPHY	ASTRONOMY/ASTROPHYSICS	PHYSICAL SCIENCES	COMM/NAV/TRAFFIC	PHOTOGRAPHIC	SPECTRO/RADIOMETRY	COMM/ANTENNA	ASTRONOMY/PHYSICS
	OPS/EXPER AREA										WORK STA ALLOCATION	
17. RADAR IMAGING UNIT	X	X								X		
18. RADAR BACK SCATTER UNIT		X								X		
19. HIGH-RESOLUTION MICROWAVE RADAR	X									X		
20. MULTIFREQUENCY POLARIZATION COHERENT RADAR					X					X		
21. HIGH-FREQUENCY SIDE-LOOKING RADAR (35 KMC)					X					X		
22. HIGH RES., COHERENT SIDE-LOOKING RADAR (8 KMC)					X					X		
23. ACTIVE VHF RADAR (75-450 MC)	X									X		
24. WIDEBAND TUNABLE RECEIVERS							X			X		
25. RF DETECTORS AND RECORDERS							X			X		
26. TRANSMITTERS - WIDEBAND							X			X		
27. LASER UNIT							X			X		
28. INTERFEROMETER UNIT							X			X		
29. ANTENNA DEPLOY/RETRACT UNIT							X			X		
30. OPTICAL SPECTROMETER							X			X		

LOCKHEED

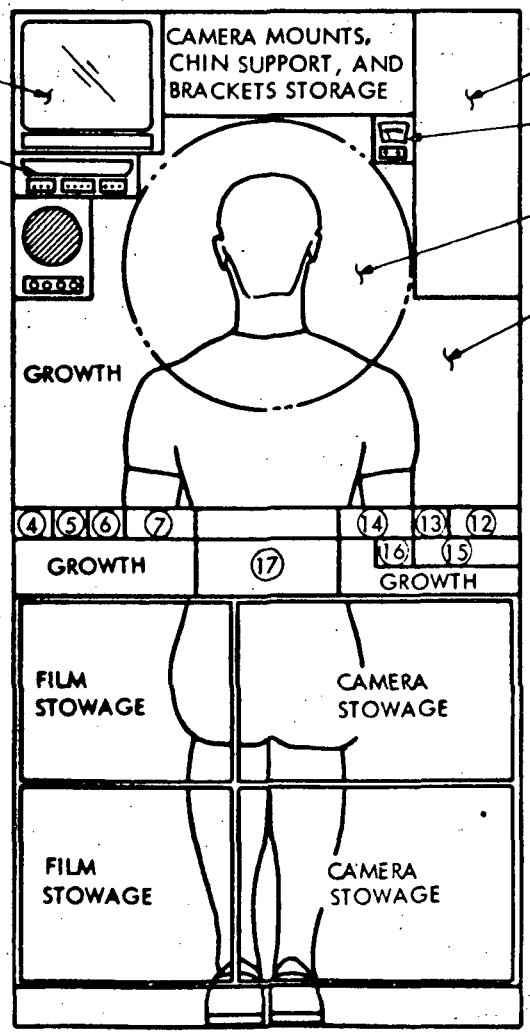
253822

OPS/EXPER C/D MODULE REQTS AND ALLOCATION (CONT)



253822A

PHOTOGRAPHIC WORK STATION*



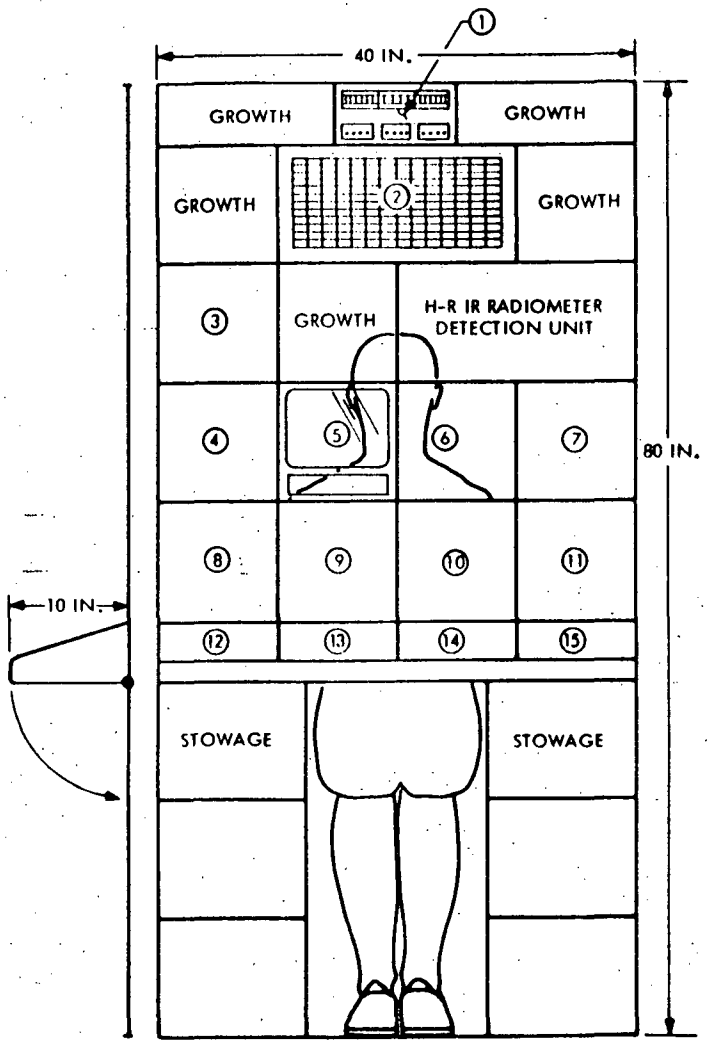
1. FIELD CHART, PROCEDURE MICROFILM DISPLAY
2. SYSTE, EVENT AND TIME LAPSE TIMERS
3. VOICE RECORDER
4. VIEW SCREEN AND FILTER SELECT
5. LENS PORT AND COVER
6. FILM SELECT
7. POWER AND C/O
8. BORESIGHT UNIT STORAGE
9. RADIATION LEVEL DISPLAY
10. VIEWING PORT
11. FREE AREA FOR CAMER SET
12. CAMERA SELECT - REMOTE
13. FILM DRIVE AND ADVANCE
14. SHUTTER/SPEED CONTROL
15. LENS SELECT, ADJUST, FILTERS AND COVERS
16. METER CONTROL - INCIDENT/DIRECT
17. KEYBOARD

*30% GROWTH POTENTIAL

LOCKHEED

253823

SPECTRO/RADIOMETRY WORK STATION



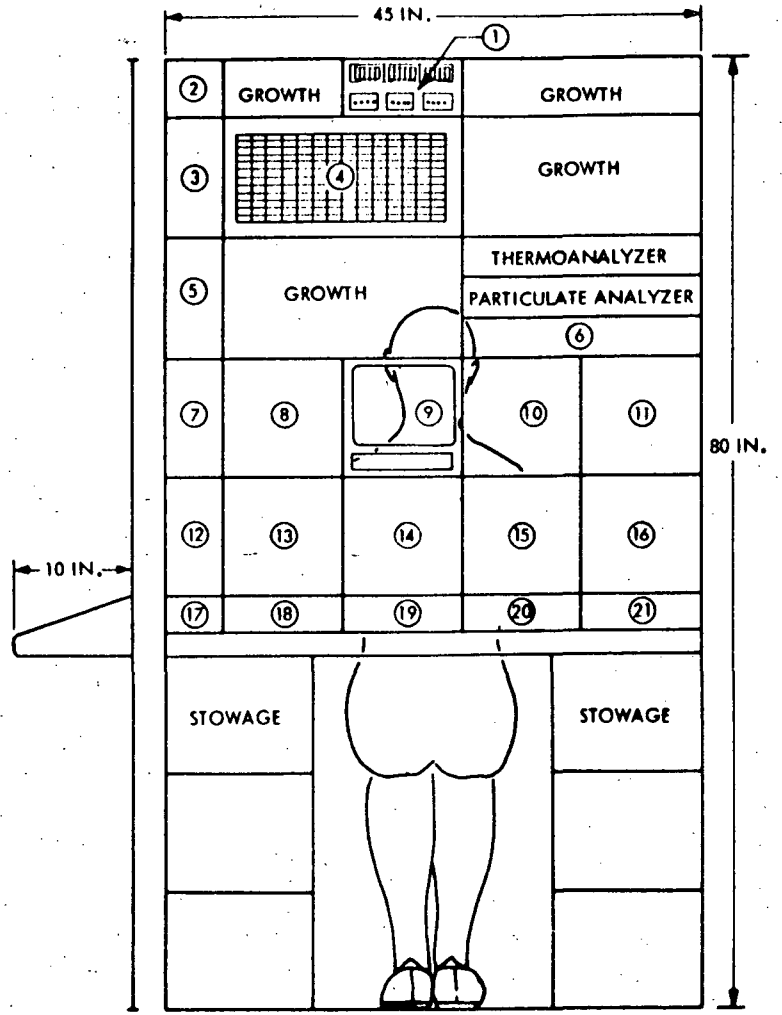
1. TIMERS/CONTROLS
2. SENSOR AND REMOTE EQUIP. STATUS
3. MULTI-CHANNEL RADIOMETER
4. MICROWAVE RADIOMETER DETECTOR
5. CRT OR MICROFILM DISPLAY
6. MULTI-SPECTRAL IMAGER
7. MICROWAVE IMAGER
8. 4-CHANNEL STRIP CHART RECORDER
9. MICROWAVE SPECTROMETER
10. IR SPECTROMETER
11. UV SPECTROMETER
12. CHART PULLOUT AND TAKEUP
13. STRIP CHART ROUTING AND CONTROLS
14. KEYBOARD
15. POWER, C/O, AND INTERFACE CONTROLS

*27% GROWTH POTENTIAL

LOCKHEED

253826

ASTRONOMY/PHYSICS WORK STATION*



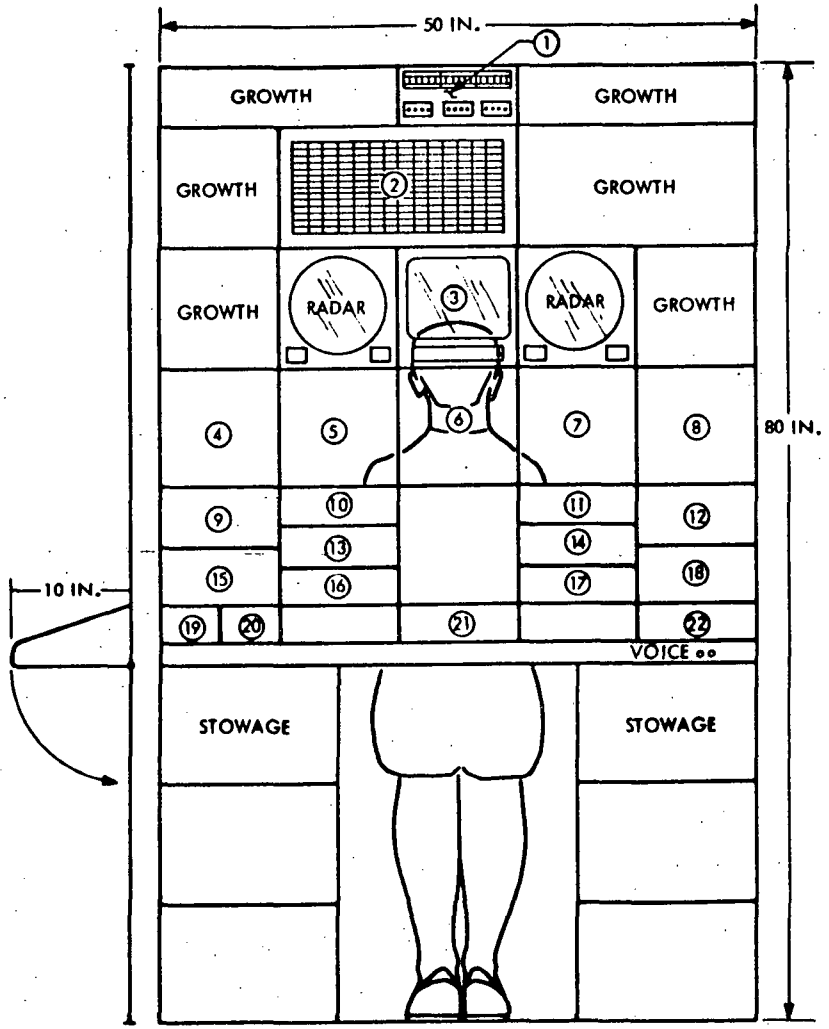
1. TIMERS/CONTROLS
2. GROWTH
3. GROWTH
4. SENSOR AND REMOTE EQUIP. STATUS
5. RADIATION MONITOR
6. ENVIRONMENT ANALYZER
7. TELESCOPE UNIT
8. RADIO ASTRONOMY UNIT
9. CRT OF MICROFILM DISPLAY
10. EMISSION LINE RADIOMETER
11. X-RAY DETECTOR
12. OPTICAL TELESCOPE UNIT
13. 4-CHANNEL STRIP CHART RECORDER
14. CORONOGRAPH UNIT
15. MAGNOMONOMETER UNIT
16. UV AND X-RAY PHOTOMETRICS UNIT
17. ANTENNA DEPLOY-RETRACT
18. CHART PULLOUT AND TAKEUP
19. STRIP CHART ROUTING AND CONTROLS
21. KEYBOARD
22. POWER C/O AND INTERFACE CONTROLS

*30% GROWTH POTENTIAL

LOCKHEED

253825

COMMUNICATION/ANTENNA WORK STATION*



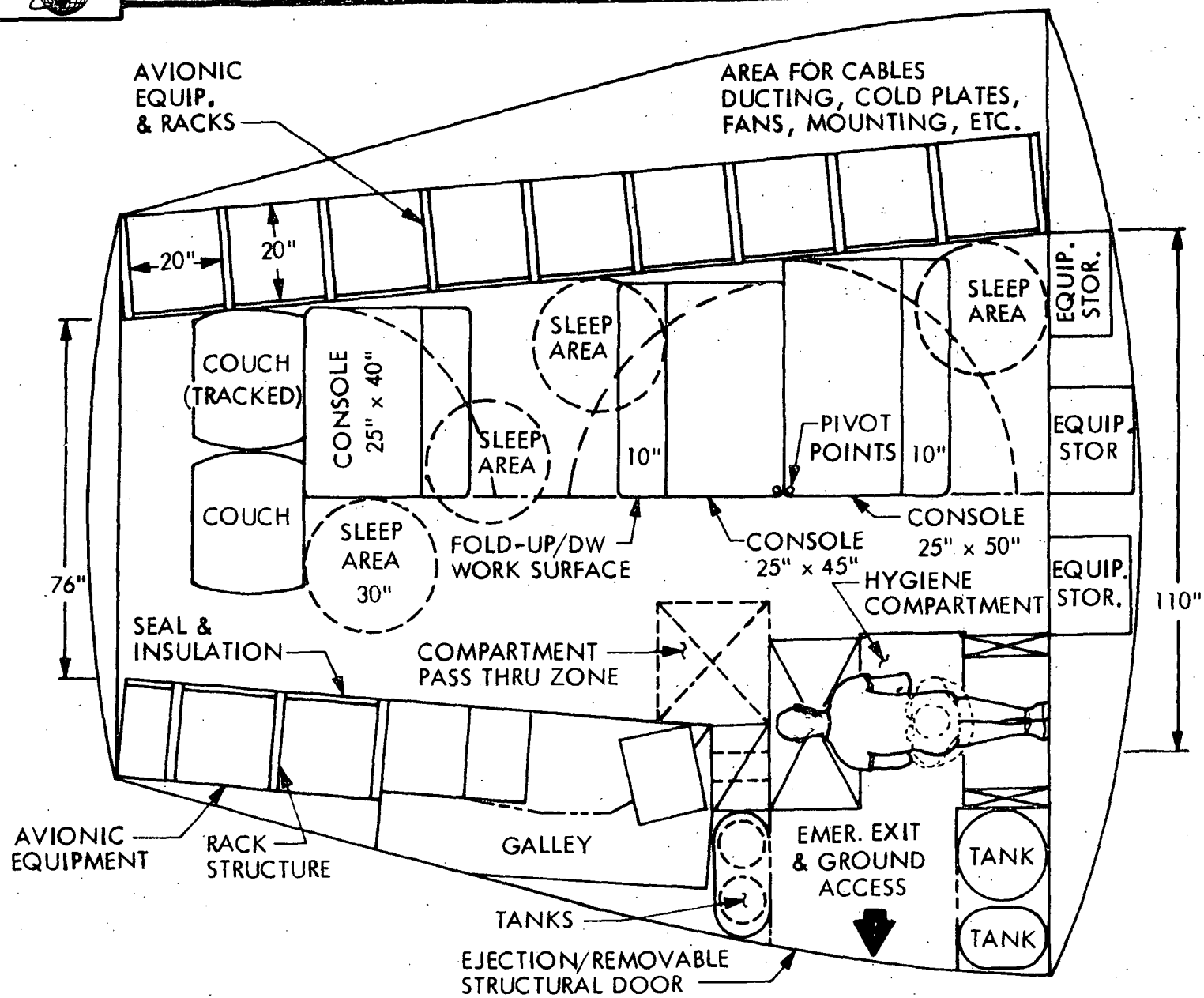
1. TIMERS AND CONTROLS
2. SENSOR AND REMOTE EQUIP. STATUS
3. CRT OR MICROFILM DISPLAY
4. INTERFEROMETER UNIT
5. R.F. DETECTORS AND RECORDERS
6. OPTICAL SPECTROMETER
7. WIDEBAND TUNABLE RECEIVERS
8. WIDEBAND TRANSMITTERS
9. ACTIVE VHF RADAR 75 - 450 MC
10. HIGH RESOLUTION MICROWAVE RADAR
11. NON-COHERENT IMAGING RADAR
12. RADAR IMAGING UNIT
13. HIGH FREQUENCY SIDE LOOKING RADAR - 35 KMC
14. COHERENT IMAGING RADAR
15. VHF PULSE REFLECTIVITY UNIT
16. HIGH RES COHERENT SIDE LOCKING RADAR - 8 KMC
17. MULTI-FREQUENCY POLARIZATION COHERENT RADAR
18. RADAR BACK SCATTER UNIT
19. ANTENNA DEPLOY-RETRACT
20. MIKE AND HEADSET
21. KEYBOARD
22. POWER, C/O AND INTERFACE CONTROLS

*33% GROWTH POTENTIAL

LOCKHEED

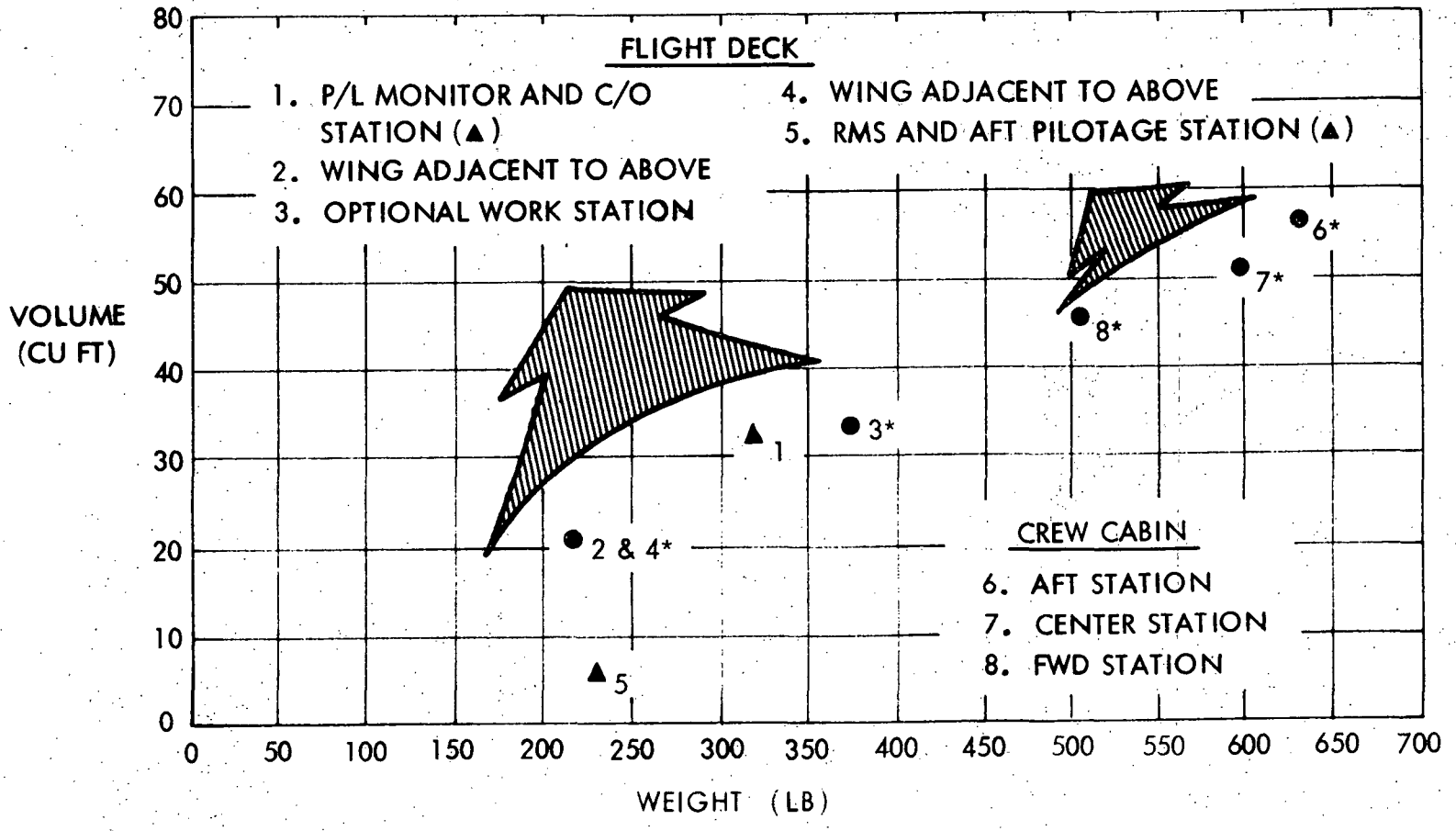
253824

CREW CABIN PLAN LAYOUT - THREE STATION CONCEPT



235202

CANDIDATE WORK STATION WEIGHT VS VOLUME COMPARISON



*BASED ON 22 LB PER CU FT DENSITY PACKAGING

▲ BASELINE STATIONS

LOCKHEED

253828